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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Full Page Advt., page 56, May 3.

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See Advertisement page 48, May 10. 2402

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See Full Page Advertisement May 3.

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WORK of all description undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work, moderate charges.—ROSSER & RUSSELL, LTD., Queen's Wharf, Hammersmith.
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See half-page Advertisement page 90, May 17. 6246

British Association of Chemists.

PROVISIONAL SOCIETY.

IMPORTANT NOTICE.

LOCAL GENERAL MEETINGS are being convened to discuss the results of the negotiations between the Executive of the Provisional Society of the British Association of Chemists and the Council of the Institute of Chemistry.

All Chemists whose qualifications conform to (A) or (B) below are invited to attend and vote on the following resolution and question:—*

(1) *That the proposals of the Institute of Chemistry, ratified by the Institute's Extraordinary General Meeting on April 27, 1918, reasonably meet the suggestions of the British Association of Chemists' Inaugural Meeting in Manchester on November 10, 1917.*

(2) *Are you in favour of the continuance of the B.A.C. after Local Sections of the Institute of Chemistry have been formed?*

*See B.A.C. Executive Report.

QUALIFICATIONS:

(A) Any person holding a University Degree (or its equivalent) with Chemistry as principal subject.

(B) Any person who can show evidence satisfactory to the Council of having had a sufficient general education and of having practised pure or applied Chemistry for not less than seven years, and who now holds a responsible position.

LOCAL SECTION GENERAL MEETINGS.
(Dates and Hon. Secretaries).

BIRMINGHAM—
F. C. A. H. Lantsberry, Esq., M.Sc., Tech., F.I.C., 63, Watford Rd., Sparkbrook, Birmingham. — Thursday, May 23, at 7.45 p.m., in the University, Birmingham.

EDINBURGH and EAST OF SCOTLAND—
R. D. W. Luff, Esq., F.I.C., 88, Ashley Terrace, Edinburgh. — Tuesday, May 28, at 7.30 p.m., in the Chemical Dept., University, Edinburgh.
Chairman—Prof. James Walker.

GLASGOW and WEST OF SCOTLAND—
W. H. Coleman, Esq., 1, Athole Gardens, Newlands, Glasgow. — Thursday, May 30, at 7 p.m., Room 23, Royal Technical College, Glasgow.

HUDDERSFIELD—
H. Royal Dawson, Esq., A.I.C., 155, Bradford Road, Huddersfield. — Meeting already held.

HULL—
H. Waites, Esq., 44, Cranbrook Avenue, Cottingham Road, Hull. — Saturday, May 25, at 3.30 p.m., in the Metropole, Marlborough Room, West St., Hull.

LEEDS and BRADFORD—
B. Hickson, Esq., M.Sc., c/o Messrs. Hickson & Partners, Ings Lane, Castleford, near Leeds. — Friday, May 24, at 6.30 p.m., in the Metropole Hotel, Leeds.

LIVERPOOL—
Dr. F. W. Kay, the Chemical Department, The University, Liverpool. — Saturday, May 25, at 4 p.m., in the Chemical Lecture Theatre, The University, Liverpool.

LONDON—
Prof. J. S. S. Brame, 3, Vanbrugh Fields, Blackheath, London, S.E. — Meeting already held.

MANCHESTER—
A. H. Goodger, Esq., B.Sc., Tech., 134, Manley Road, Whalley Range, Manchester. — Friday, May 31.

NEWCASTLE-ON-TYNE—
Dr. J. H. Paterson, The Green, Wallsend-on-Tyne. — Saturday, May 25, at 3 p.m., in the Mining Institute, Newcastle-on-Tyne.

NOTTINGHAM and DERBY—
Dr. E. P. Hedley, c/o Messrs. The British Cellulose Company, Spondon, near Derby. — Wednesday, May 29.

SHEFFIELD—
G. R. Bolsover, Esq., Assoc. Met., 31, Rosington Road, Brocco Park, Sheffield. — Meeting already held.

SOUTH WALES—
H. Mansfield, Esq., F.I.C., Westmore, Ferryside, South Wales. — Saturday, May 25, at 3 p.m., in the Stephney Hotel, Llanelly.
Chairman—Dr. J. W. McDavid.

An Admission Ticket, Ballot Paper, Executive Report and Circular can be obtained on application to the Local or General Secretaries.

Chemists unable to attend should send their completed ballot paper to the Local Secretary (envelope marked "Ballot") or to the General Secretary if not resident in any of the above section areas.

NOTICE.

A NATIONAL GENERAL MEETING of the B.A.C. will be held in Manchester, at the College of Technology, Sackville Street, on Saturday, June 15, 1918, at 2.30 p.m., Dr. Alfred Ree in the Chair.

At this Meeting the result of the voting of Chemists in Local Sections on the above resolutions will be reported, and the recommendations from these sections will be discussed.

Tickets of admission can be obtained by Chemists having qualifications (A) or (B) above, on application to the General or Local Secretaries.

Signed on behalf of the Executive Committee,
T. P. B. RHEAD,
Hon. General Secretary.
10, Malvern Road,
Acocks Green,
Birmingham. L 467

The Manchester Steam Users' ASSOCIATION.

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APPOINTMENTS OPEN.

RADCLIFFE EDUCATION COMMITTEE.

The Committee are prepared to receive

Applications for the Post of PRINCIPAL of the Technical School, with

which will be combined the duties of Head Master of Junior Technical School, which latter is proposed to be opened in September next.

Applicants should possess a University Degree, or its equivalent. Preference will be given to those having practical experience in Engineering.

Further particulars can be obtained on application.

Commencing salary £300 per annum.

Applications, endorsed "Principal," should be in the hands of the undersigned not later than Noon on Monday, June 3rd next.

S. MILLS,
Secretary.

Council Offices,
Radcliffe, near Manchester.
May 16th, 1918. L 441

NEWTON-IN-MAKERFIELD HIGHER EDUCATION COMMITTEE.

JUNIOR TECHNICAL SCHOOL.

The Committee require the

Services of a Headmaster of a Junior Technical School (to be opened in

September) and of Evening Technical Classes. Applicants should be Graduates (or have equivalent qualifications) with previous experience of Technical Education. Commencing salary £300.—Applications should be sent, before June 15th, to the CLERK to the Council, Town Hall, Earlestown, Lancs, from whom further details may be obtained. L 439

COUNTY BOROUGH OF MIDDLESBROUGH EDUCATION COMMITTEE.

The Middlesbrough Education Committee invite

Applications for the following POSTS for TEACHERS in a Junior Technical School to be opened in August next.

Head Master with B.Sc. in Engineering. Salary, £375 (with £16 War Increment).

Assistant Master (Physics and Chemistry). Salary, £180 (with £16 War Increment).

Assistant Master (English and Mathematics). Salary, £180 (with £16 War Increment).

Assistant Master (Woodwork). Salary, £180 (with £16 War Increment).

Applicants should state in detail their educational qualifications and their educational experience in Technical School work, and before making an application should write for a "Report" dealing with the new School. Last day for receiving applications, 5th June, 1918.

EMMERSON BECKWITH,
Director and Secretary.
Education Offices, Middlesbrough.
13th May, 1918. L 455

COUNTY BOROUGH OF BARROW-IN-FURNESS TECHNICAL SCHOOL.

Applications are Invited for the Two vacant posts of ASSISTANT LECTURERS in ENGINEERING at the above

School. The successful candidates will be required to commence duties in September. Salary £150, rising to £200 per annum, according to scale. In fixing the commencing salary, allowance will be made for previous experience. Full particulars as to duties, &c., and copy of Scale of Salaries may be obtained from the DIRECTOR OF EDUCATION, Town Hall, Barrow-in-Furness, to whom applications must be sent not later than noon on Saturday, 8th June, 1918.

By Order,
L. HEWLETT,
Town Clerk and Clerk to the
Town Hall, Local Education Authority.
15th May, 1918. L 478

MUNICIPAL TECHNICAL SCHOOL, LONDONDERRY.

The Technical Instruction Committee require the

Services of a Lecturer in Mechanical Engineering, to commence duties

in September next. Salary £160 per annum. Forms of Application and further information may be obtained from the PRINCIPAL at the School. Forms of Application must be returned on or before Thursday, 6th June, 1918. L 431

J. A. WILLIAMS,
Secretary.

Chemist Required, for Large

Motor and Aeroplane manufacturing concern, must be used to the analysis of both plain and alloy steels. One with experience in other engineering materials preferred. No one on Government work considered.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, quoting reference No. A 5124. L 349

A Well-known Engineering

Firm in the south of England REQUIRE the SERVICES of an ASSISTANT WORKS SUPERINTENDENT to take charge of night shifts. Must have a knowledge of works routine and have had experience in the handling of labour (male and female). If applicant called upon to do any day-work he will have to supervise all outside work in connection with the Works Department. Applications from discharged officers will be considered. No one already engaged on Government work need apply.—Write, stating salary required and giving full details of experience to, your nearest EMPLOYMENT EXCHANGE, mentioning No. A. 5084. L 400

Wanted, Two Good Capable

ELECTRICIANS, must have had experience of bells, telephones, and lighting. Plant supervision essential.—Apply, stating age, references, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5309. No person already employed on Government work will be engaged. L 464

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good man with engineering experience, to take full charge.—Apply, stating experience, salary expected, and when free, "ALPHA," WM. PORTEOUS & Co., Advertising Agents, Glasgow. L 476

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For construction of a new 50,000 tons Rolling Mill WANTS a First-class

Rolling Mill Engineer

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Applications requested to the direction of
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L 518

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REQUIRE immediately SEVERAL ENGINEERS-IN-CHARGE for their Power House. Candidates must have had experience with B.H.T. turbo generators of not less than 6000 K.W. capacity, and B. & W. Marine type Boilers; and be well versed in maintaining works costs at a minimum. Commencing salary £300 per annum.—Apply, stating age, etc. to BOX No. L 529, Offices of ENGINEERING.

Manufacturing Experts

WANTED. — General Manager, Costing Clerk, Draughtsman, Sales Manager and Efficiency Engineer Wanted for old-established Tractor and Implement business growing rapidly. These are permanent posts with good future for right men. No one on Government work need apply.—Reply, giving age, experience, references, and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 542.

Mechanical Engineer, Re-

QUIRED for Glass Works where extensions are in progress; must be good draughtsman and have experience of Siemens regenerative furnaces and the design of special purpose machines. The ability to handle correspondence and enquiries for materials will be a qualification for the post.—State age, experience and salary required.—Address, L 548, Offices of ENGINEERING.

The Gentlemen who Replied

to our Advertisement, No. L 34, for a Works Manager, are thanked for their application, and are respectfully informed that the VACANCY is NOW FILLED. L 557

Engineer (Works) Wanted.

To be responsible, under Chief Engineer, for the running, upkeep and erection of large factory plant, including Boilers, Turbo Generators, large Gas Engines, Diesel Engines, &c. Must have had thoroughly technical and practical training and have held a similar position. Previous experience in a chemical factory an advantage. State fullest particulars, with copies of testimonials and salary required. (See War Notice.) — Address, L 526, Offices of ENGINEERING.

Engineer Required, accus-

tomed to the erection and installation of heavy electrical plant, including turbo alternators and rotary converters. Must have good technical knowledge, initiative and experience in the control of men. No person already engaged on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, giving age, full particulars of experience and salary required and quoting No. A. 5323. L 500

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neering knowledge WANTED, to control and organise Progress Department of large Aircraft Works, and to be responsible for distributing work in shops. Must have had similar experience with an up-to-date firm.—Apply, stating age, experience and salary required, to nearest EMPLOYMENT EXCHANGE, mentioning this paper and L 502. No one already on Government work can be engaged.

Engineer Wanted, for Large

Modern Cement Works.—Address, stating age, experience and salary required, L 513, Offices of ENGINEERING.

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REQUIRED for special tools. Good opportunity for a really smart man. Controlled factory. Reply, stating qualifications and salary. No one already on Government work need apply.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5327. L 475

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WANTED for the Midlands; preference given to men with experience in the design of D.C. and A.C. Machines or Transformers.—Apply, stating age, experience and salary required to your nearest EMPLOYMENT EXCHANGE, mentioning this paper and No. A. 4895. Nobody engaged on Government work will be engaged. L 474

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Wanted Immediately, for a

large Government-Controlled Factory in the Midlands,

A NUMBER OF
JIG & TOOL DRAUGHTSMEN,
DETAIL DRAUGHTSMEN,
FITTERS,
TURNERS,
UNIVERSAL MILLERS,
UNIVERSAL GRINDERS,
TOOL SETTERS
for Acme & Cleveland Automatic Machines,
GEAR CUTTERS,
TOOL FITTERS,
WOOD MACHINISTS,
FOR ABRO WORK.

Only those who are of British nationality and who possess the highest skill will be considered.

No person already employed on Government work will be engaged.

Applicants should apply to their nearest EMPLOYMENT EXCHANGE, mentioning No. A 5330. L 492

Draughtsman Wanted, with

sound mechanical Engineering knowledge and training. North London District. No one at present on Government work or residing more than ten miles away need apply.—Address L 480, Offices of ENGINEERING.

Draughtsmen.—Several Men

REQUIRED for Mechanical Engineering work for Controlled Factory in Midlands. Must have had some practical experience. Knowledge of Textile or Printing machinery desirable, but not essential. Good opportunities for suitable men. Also several good JUNIORS, with Drawing Office experience. No one already on Government work will be engaged.—Apply, stating full particulars of salary required, age, experience, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5081. L 416

Draughtsman Required, with

good experience in design of Steelworks Machinery preferred, although applications from high-class men with other experience would be considered. No one already on Government work will be engaged.—State age, experience and salary required and when at liberty, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 4694. K 393

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THE LARDERELLO NATURAL STEAM POWER PLANT.

By UGO FUNAIOLI, *Director of the Electrical Department of the Società Boracifera di Larderello.*

(*Concluded from page* 508.)

THE idea of using the natural steam springs of Larderello for obtaining motive power, was often considered, but until comparatively recently no definite steps were taken to make the necessary experiments. In 1897 the natural steam was used as a means of heating water in a boiler, and the pure steam so produced, was employed for driving a small steam engine. Nothing more was attempted until 1905, when Prince Ginori Conti, general director of the Larderello works, and now chairman of the Società Boracifera, decided to make experiments for the use of natural steam in a piston engine. The results were so satisfactory, that in 1906 a larger engine was experimented upon, and was used for driving a dynamo for illuminating the works. This engine has now been working for over ten years regularly, and shows no signs of wear or of corrosion from the use of the natural steam.

A further step was decided upon in 1912 by putting up a 250-kw. turbo-generator. It was originally intended to work the turbine with natural steam, but for two reasons the use of intermediate boilers was decided on instead, adopting the natural steam as a means of heating or of fuel. The first reason was the doubt as to the manner in which the blades of the turbine would have been affected by the gases contained in the natural steam. The other reason was the difficulty of obtaining sufficient vacuum in the condenser, on account of the uncondensable gases which the natural steam contained. This plant was inaugurated in 1913, and was used for generating three-phase current at 4,000 volts, which was raised partly to 16,000 volts for distribution on overhead lines to Volterra, Saline, and to two of the company's works; and partly reduced to 220 volts for distribution in Larderello. Encouraged by the good results given by this plant, the company decided on a bolder venture, and a large power station was erected in Larderello with three units of 2,500 kw. each.

The works were begun in 1914, but were delayed by the European War. The first unit was started in 1916,* and the power station was completed also in the same year. The boilers, or more correctly speaking, the evaporators, were designed by a French firm, Messrs. Paul Kestner of Lille; but they were actually constructed by Messrs. Mussi of Milan. These evaporators consist of a number of aluminium tubes contained in a shell of sheet iron. The natural steam circulates outside the tubes, while pure steam is generated inside the tubes, on the principle of the ordinary water-tube boiler. Aluminium was adopted for the water tubes instead of iron or steel, because the sulphuric acid contained in the natural steam would form a layer of sulphide of iron on the exterior surface of the tubes lowering thereby the coefficient of transmission of heat.

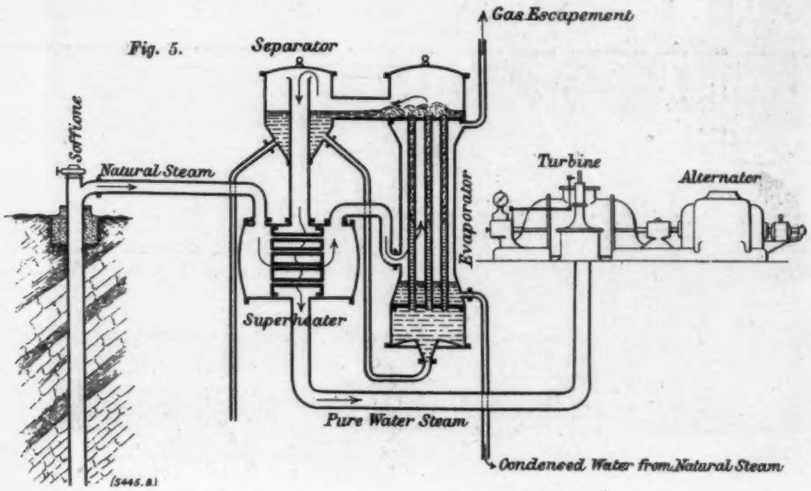


FIG. 6. LOWER PORTION OF EVAPORATORS.

FIG. 7. UPPER PORTION OF EVAPORATORS.

The tubes contained in each element are about 300; they are about 7 m. long, and have a diameter of 30 mm., and are disposed vertically. The pressure of the natural steam is about 1 atm. effective, and that of the pure steam generated in the evaporators is 0·5 atm. effective. The natural steam condenses partly in the evaporators, and the rest is discharged by an exhaust pipe, together with the uncondensable gases. These are collected for the extraction of carbonic acid, and, in the future, of helium. A diagrammatic view of the arrangement of the evaporating plant is given in Fig. 5, annexed, while photographic views of the evaporators are given in the adjoining Figs. 6 and 7.

Each element is calculated to produce about 6,000 kg. of pure steam per hour. This pure steam generated within the aluminium tubes, is collected at the higher end of the evaporator element, and passes through a separator, where it deposits the water which may be brought up with it. A separator is provided for every two evaporator elements, and these are united together in groups of eight elements, sufficient for one turbo alternator set. Two groups of evaporators are actually at present in working order, and others are being mounted. Previous to entering the turbine, the pure steam is superheated, by means of natural steam, which passes through the superheater before reaching the evaporator elements.

The feed water for the evaporators can be provided in two ways, *i.e.*, by sending into the evaporators condensed steam from the surface condensers;

* See ENGINEERING, vol. cii, page 487.

or by using as feed water, that produced by the condensation of natural steam outside the evaporator tubes. The second system has the advantage of providing water at a temperature of over 90 deg. C. Of course, the first system provides the purer water; though no practical damage has proved to result from the use of condensed natural steam. The feed-water pumps are of the duplex type, and natural steam direct from the springs is used in the piston engine working the pumps.

The turbo generators were provided by the well-known Italian firm of Messrs. Franco Tosi, of Legnano, near Milan. The turbines are of entirely Italian manufacture, and have been designed by Messrs. Tosi to meet the special demands of this plant. Each turbo-generator is capable of a maximum output of 3,000 kw. with 3,000 r.p.m. The actual net output is 2,500 kw.

The steam being generated by the evaporators at a pressure of 0·5 atm. effective, a certain allowance is made for loss of pressure in the steam supply pipes, so that 0·25 atm. effective is the pressure regarded as available at the admission valves of the turbines.

Steam consumption being about 14 kg. per net kilowatt-hour, over 35,000 kg. of steam pass into each turbine per hour, and the admission valve is made of ample dimensions for the purpose of dealing with such large amounts of low-pressure steam. Each turbine itself is really composed of two turbines, the inlet for the steam being at the centre. This device has the advantage of eliminating any longitudinal thrust, besides reducing the diameter of the turbine wheels. The turbines are entirely built on the reaction or Parsons type. Seven stages of expansion are allowed on each side of the rotor; the first five being fitted with brass blades and the remaining two with 5 per cent. nickel steel blades.

The condenser is of the surface-cooling type, and contains about 3,000 brass tubes of 22 mm. diameter, and 4·5 m. in length. A centrifugal pump directly coupled to an electric motor, drives the cooling water through the tubes, and sends it on to the refrigerating tower. Each pump requires about 300 h.p.

Instead of air pumps, two hydraulic ejectors are installed below the condenser, the cool water from the refrigerator tank, arriving at the ejectors and passing on to the centrifugal pumps. Special attention has been paid to all details connected with the condensing plant, because the output of the turbines depends mainly on the efficiency of the vacuum obtained in the condenser; the admission pressure of the steam being, as stated above, only $\frac{1}{4}$ atm. It is intended to give a detailed description of these turbines, with particulars and drawings, in a separate article.

The cooling water is sent on to the refrigerating towers through an iron pipe of about 900 mm. in diameter. The refrigerating towers have a capacity of about 1,200 cub. m. per hour; and are naturally of ample dimensions, being of the natural draught type. Two of these towers are actually in use, while a third is being erected. The structures are entirely of wood, while the reservoir under each tower is made of reinforced concrete. Figs. 8 and 9, annexed, give views of these towers and of their foundations in course of construction.

The towers are of about 25 m. in height, of which about 6.5 m. are actually occupied by the cooling structure, the rest being the flue for the natural draught. The reservoirs are 30 m. in length, and 18 m. in width. The fall in temperature given by the towers is about 10 deg. C. Owing to the methods adopted for supplying the refrigerators, the boric acid contained in the water resulting from the condensation of the natural steam is not lost, but is capable of being extracted by the Chemical Department. The alternators are directly coupled to the turbines. They are three-phase for 50 periods at 3,000 r.p.m. The current is generated at a potential of 4,000 volts. Two of the alternators were provided by Messrs. Brown Boveri, and the third by the Siemens Schuckert Company. The exciting dynamos are co-axial with the alternators. It is also possible to excite any of the alternators by means of a rotary converter. Each of the alternators is provided with an air filter, the use of which has proved very beneficial.

The connections between the alternators and the switchboard consist of aluminium bars running in a special gallery under the terrace leading to the generating station. The switchboard itself is of a very simple type, and contains only the essential apparatus for controlling the alternators, and running them in parallel.

The step-up transformers for raising the voltage from 4,000 to 36,000 are placed in an adjoining building, containing also the high and low tension switches, and the lightning arresters. The transformers actually installed are four, each transformer being sufficient for 2,860 k.v.a. They will be seen in Fig. 10, Plate LII. They are all of the self-cooling oil type, and the high tension value can range from 32,000 volts to 40,000 volts.

The high-tension coils are divided into two parts, which can be connected in series or in parallel, so as to have a voltage of about 17,000 volts. This has been done in order to use these large transformers for some minor transmission lines belonging to the society. Three of these transformers have been built in Milan, by the Società Elettrotecnica Galileo Ferraris (formerly Thomson Houston) and the fourth at Vado Ligure near Savona, by the Italian Westinghouse Company. Two other large transformers, also built at Vado Ligure, for 4,000 k.v.a., are in course of erection.

The second storey of the transforming station is reserved for the automatic oil switches of the transformers, and of the transmission lines, seen in Figs. 11 and 12, Plate LII. These switches are of American construction, by the General Electric Company. The third storey, shown in Fig. 13, Plate LII, contains the bus-bars in aluminium, both for 4,000 volts and for 40,000 volts, and the last storey is occupied by the lightning arresters. These are all of the well-known Gola type, which have given very satisfactory results. Earth transformers are provided for static discharges.

Another smaller transforming station is provided for raising the tension from 4,000 volts to 16,000 volts for distribution in the region around Larderello. Four overhead lines at 36,000 volts diverge from the transforming station: (1) A line from Larderello to Siena, connecting the former with the Valdarno system, which distributes electrical energy in the eastern part of Tuscany, including Florence. Larderello runs in parallel with the power stations of the Società Mineraria, and with the hydraulic power stations near Terni. (2) A line from Larderello to Leghorn, connecting it with the Ligure Toscana power stations, with which it also runs in parallel. (3) A line from Larderello to Piombino, for the important iron and steel works in that town. (4) A line from Larderello to Massa, for the iron and copper pyrite mines. Minor lines, as beforesaid, at a tension of 16,000 volts, and belonging to the Società Boracifera, connect the various works, and convey electric power as far as Volterra. These last lines are completely in aluminium. As yet but two of the turbo alternators of 2,500 kw. are used, one of the three installed being kept as reserve. It is expected that in a short

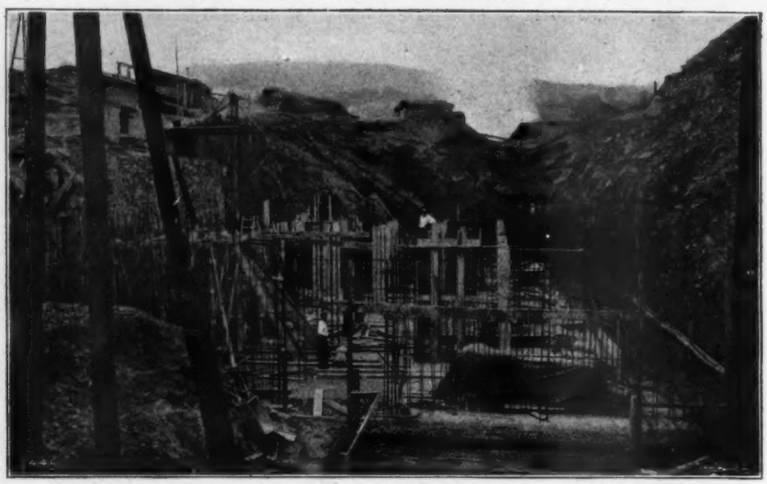


FIG. 8. VIEW SHOWING CONSTRUCTION OF RESERVOIR FOR COOLING TOWERS.

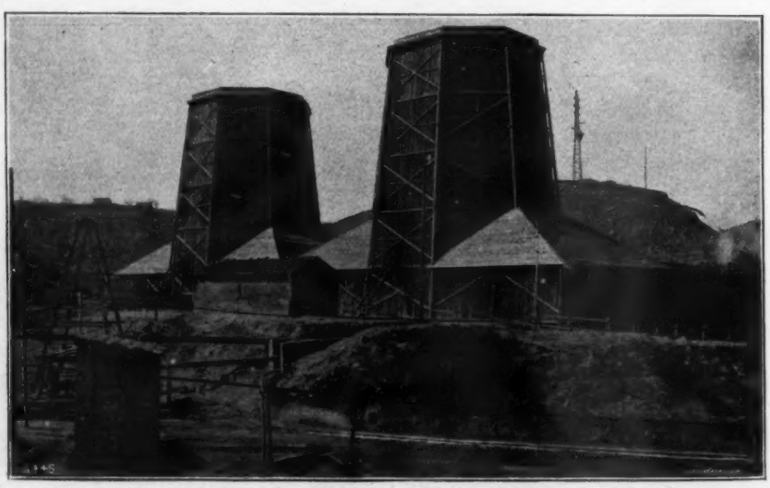


FIG. 9. COOLING TOWERS.

THE LARDERELLO NATURAL STEAM POWER PLANT.

(*For Description, see Page* 567.)

FIG. 10. TRANSFORMER STATION WITH OIL-COOLED TRANSFORMERS.

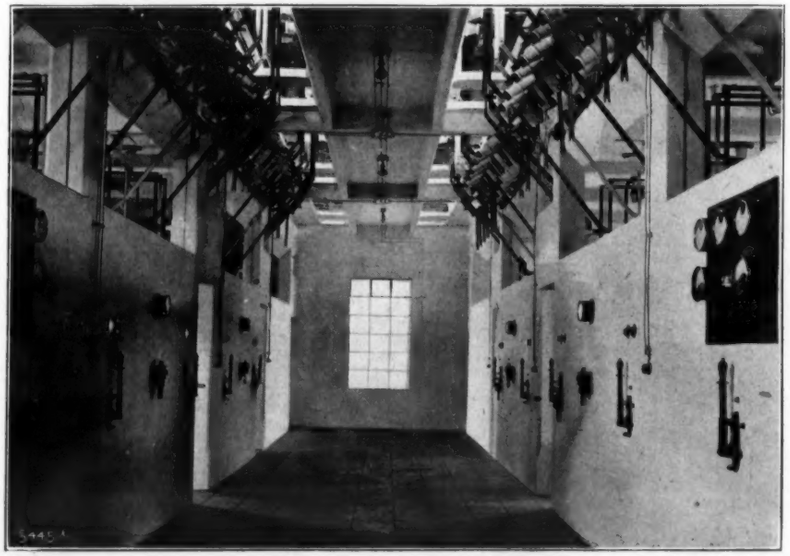


FIG. 11. TRANSFORMERS AND LINE SWITCHES.

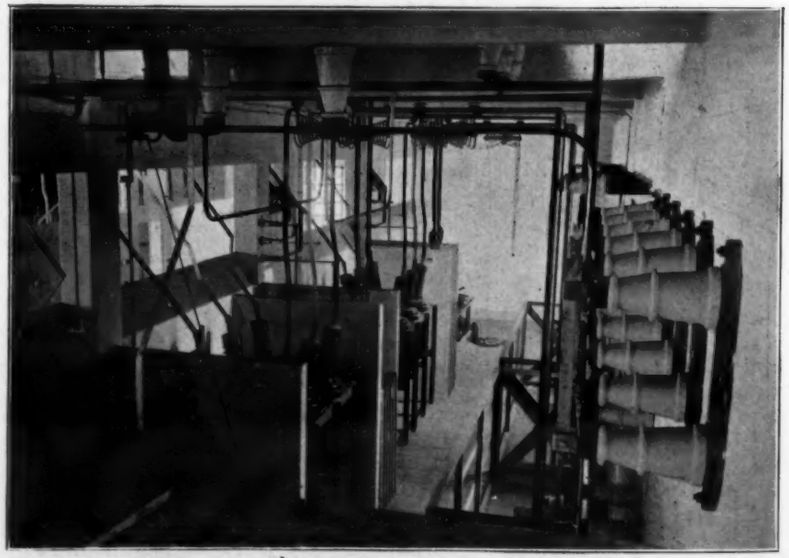


FIG. 12. TRANSFORMERS AND LINE SWITCHES.

FIG. 13. HIGH AND LOW TENSION BUS BARS.

(*To face page* 568).

THE LARDERELLO NATURAL STEAM POWER PLANT.

(*For Description, see Page* 567.)

Fig. 14. View of Works at Larderello, with Power Station and Collecting Tanks.

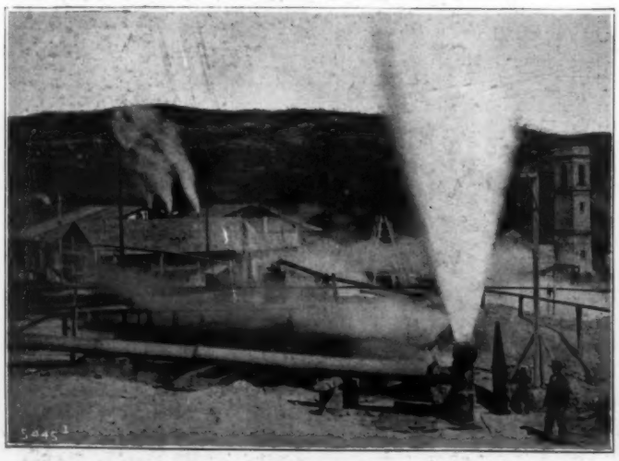


Fig. 15. A Powerful "Soffione" at Larderello.

Fig 16. Concentrating Planes for Dealing with Water containing Boric Acid.

THE LARDERELLO NATURAL STEAM POWER PLANT.

(*For Description, see Page 567.*)

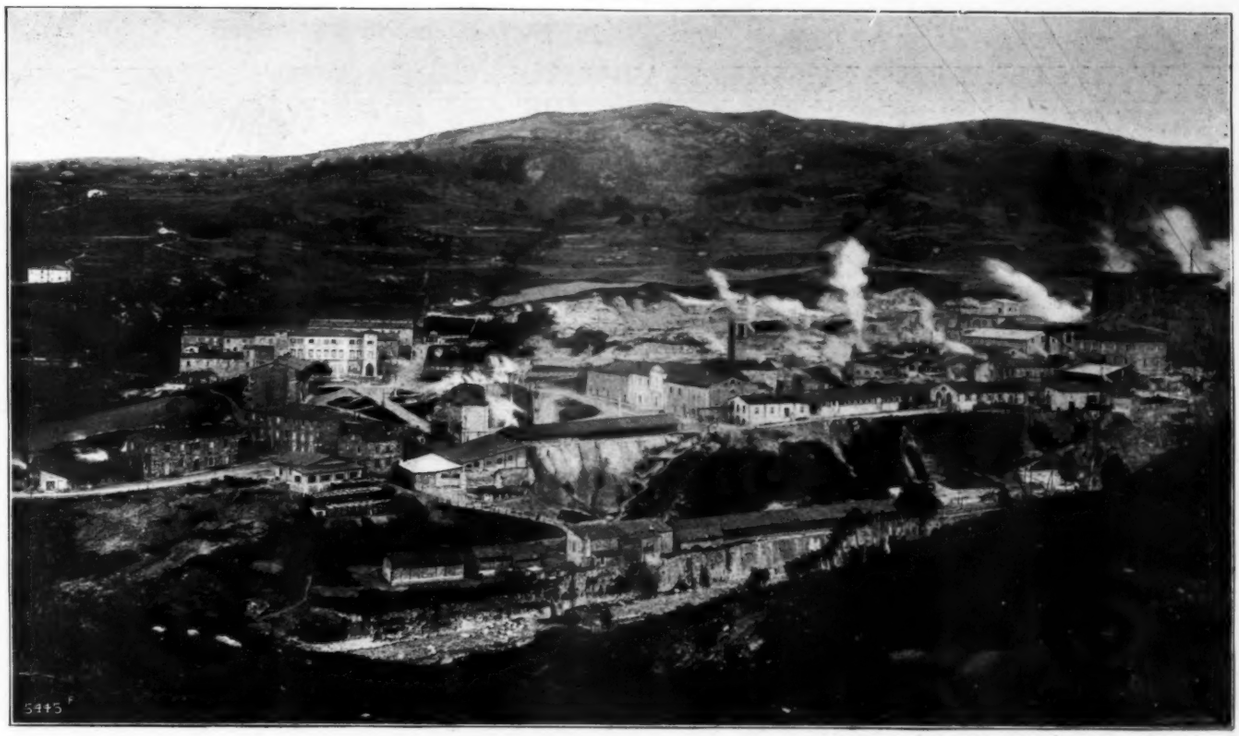


FIG. 17. GENERAL VIEW OF LARDERELLO.

FIG. 18. VIEW OF POWER STATION, SHOWING TRANSFORMER STATION AND COOLING TOWERS.

THE LARDERELLO NATURAL STEAM POWER PLANT.

(*For Description, see Page* 567.)

Fig. 19. General View of Boric Works at Lago.

Fig. 20. A Powerful "Soffione" at Lago, Discharging about 25,000 Kilogrammes of Steam per Hour.

(*To face page* 569.)

time 5,000 k.w will be distributed. Steps are being taken for the putting up of a fourth group, so that three turbines may be run, giving 7,500 kw. Further experiments are also in progress for utilising direct natural steam in the turbines. This idea, which had been abandoned in the case of the Larderello plant, has been taken up again in another of the society's works at Lago. In that locality a notable quantity of natural steam is available, and the nature of the soil is specially favourable for perforation. A steam well at Larderello requires often more than five or six months of continuous work before it is ready for use, while at Lago, three or four months may be sufficient, and in some cases even less, the well being ready for explosion at a smaller depth than at Larderello."

Besides this, recent accurate measures and experiments have proved that the quantity of gas contained in the steam at Lago, is notably less than that of Larderello, the latter being 5 per cent. in weight, while the former is only about 3 per cent. Thus one of the principle difficulties which forbade the use of direct natural steam, *i.e.*, the presence of notable quantities of gas to be removed from the condenser, would be in part eliminated. As to the action of the gas on the turbine blades, experience at Larderello has shown that it is certainly not of paramount importance, if the right qualities of metal be used, and certain precautions taken.

With regard to the extraction of the gases from the condenser, air pumps would have to be provided in adequate proportion to the gas itself, and while these would, of course, require a certain amount of driving power (lessening thereby the output of the turbines), on the other hand the abolition of the evaporators would increase the total efficiency of the system. Jet, instead of surface condensers, could also be used, thereby reducing the cost of the whole plant, a further noticeable reduction being obtained by the abolition of the evaporators. Following these considerations, an experimental plant has just been completed at Lago, by installing there the small turbine of 250 kw. first used at Larderello.

Signor Plinio Bringhenti, engineer of the society, who studied the Larderello plant, is experimenting at Lago with a new type of separator invented by him for eliminating gas from the natural steam, before it enters the turbine. If these experiments give the result that is hoped for from them, a decisive step will have been taken towards the rational and complete solution of the problem. Designs are being got out for the erection of a much larger plant at Lago, capable of developing over 10,000 kw.

On Plates LIII and LIV are given a series of views of the works dealt with above. Fig. 14, Plate LIII, is a general view of the works at Larderello showing the power station with cooling towers and the shallow reservoirs used for collecting the water containing boric acid. Fig. 15, on the same plate, shows a powerful "Soffione" open at Larderello, the discharge being at the rate of about 14,000 kg. of steam per hour. Fig. 16, also on Plate LIII, shows a range of evaporating planes for concentrating the water containing boric acid. Of the two views on Plate LIV, the upper one, Fig. 17, is a general view of Larderello, while Fig. 18 is a view of the power station at Larderello with the transforming station and cooling towers. Finally, on Plate LV, Fig. 19 is a general view of the boric works at Lago, where, as stated above, an experimental station for the direct use of the natural steam in the turbines has been erected; while Fig. 20, below, shows one of the powerful "Soffione" at Lago, the steam being let off through two orifices and the discharge being about 25,000 kg. per hour.

The present condition of Italy with regard to fuel is well known. For the industrial developments of this country, all natural sources of energy must be turned to account. While the northern part of the Italian Peninsular is rich in water power, such is not the case of Tuscany, where the water courses derived from the Apennines, and utilised in the important power stations of the Società Ligure Toscana, are subject to long periods of draught. Lignite is used as fuel in the large power station of the Società Mineraria del Valdarno, and the distillation of peat at Orentano, near Lucca, produces gas which is utilised in gas motors, while natural gas springs near Pisa are being used for the illumination of that town, and will also be used for motive power.

Still the demand for electric power is steadily increasing, and the more complete utilisation of the natural steam springs cannot fail to prove of the greatest importance for meeting this increasing demand. The courageous initiative of Prince Ginori Conti, who has steadily worked for years towards the solution of the problem of utilising the natural steam springs, is therefore well worthy of praise. Following his initiative other studies are also being made for the utilisation of latent volcanic energy near Naples, at the famous Solfatara of Pozzuoli. No definite previsions can be made at present as to the further development of these systems, but one is certainly led to consider the possibility that, volcanic energies, hitherto only regarded as a source of danger, may, in the future become beneficial factors in our national economy.

TEMPLETS, JIGS AND FIXTURES.—No. V.

By JOSEPH HORNER.

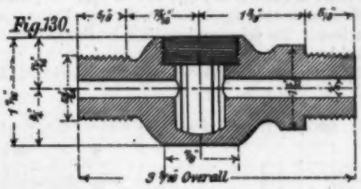
SOME examples of jig-fixtures used by Messrs. Ruston, Proctor and Co., Limited, of Lincoln, are illustrated in this article. A jig-fixture is shown by Figs. 125 to 129, for machining asbestos-packed taps for cylinders, shown by Figs. 130 and 131. It is a closed fixture, the hinged cover with its plate comprising the drilling jig.

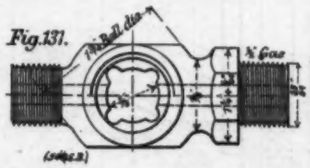
The box portion A, lies on the machine table. It is not secured thereon, but is moved about to bring the various holes under the drilling spindle. Its hinged cover B encloses the work. The body A is recessed circularly to carry the covering jig plate C, shown separately in Fig. 128. The cover is rotated in its recess, and locked by a spring plunger D (seen in detail in Fig. 129) for the several drilling positions, entering vertically the outer set of four holes in the plate, Figs. 125 and 128. The plate C has a flat which is provided to enable the hinged portion B to be easily turned over to remove the chips during the various operations, by simply turning the plate C round to clear.

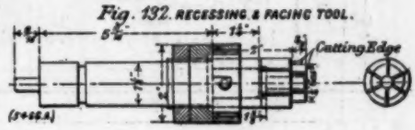
The tap body, Figs. 130 and 131, is located centrally in the fixture by its globular portion, Fig. 125, and in the axial direction by a split bush E, Figs. 126 and 127, bored to take the ¼-in. gas thread in that end of the body. The other end has a clearance in the fixture. The grip is got between the body A of the fixture and the hinged cover B, which here (see Fig. 125) forms a holder for the casting gripped between the two, and is tightened on it with a ⅜-in. square head screw F. Any number of castings will therefore be turned out alike in relation to the globular outside, the screwed end, and longitudinally.

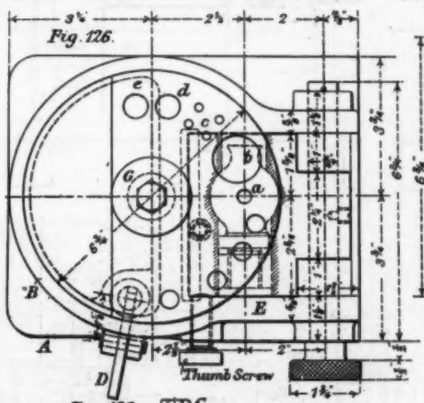
The jig plate C is secured to the base by a central stud G, fitting in a central pin which is tapped into the body of the jig. This, with the coercion of the bored recess in the cover permits the holes in the jig plate C to be brought round over the centre of the globular body for the various operations in the centre hole, which is the sole function of this appliance. Six operations are required. The first is to drill a ⅜-in. hole, as seen in position at *a*, Fig. 126. The jig plate is then brought round and locked with the 1¼-in. hole *b* over the centre, in which hole as a guide the body of the counterboring and facing tool, Fig. 132, passes, fitting the hole exactly, counterboring for the gas thread, and facing the metal above with the reaming and milling formed edges. The depth of cut is determined by the stop collars that are screwed to the body of the tool. The hole for the asbestos-packed plug requires three operations. Four $\frac{5}{16}$-in. holes are drilled first through the four small holes *c* in the jig plate, the setting out of these being seen enlarged in Fig. 133. Then a ⅜-in. hole is drilled through the hole *d* to allow for reaming through the next hole, *e*, followed by the spirally-fluted reamer, Fig. 134, in this hole. The gas thread is then tapped, apart from the use of the plate.

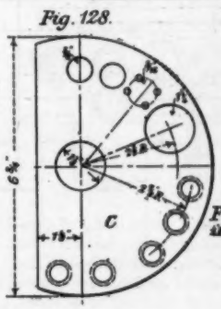
The group of Figs. 135 to 140, show a drilling jig

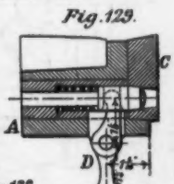


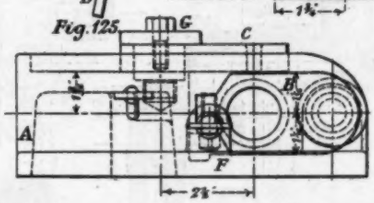


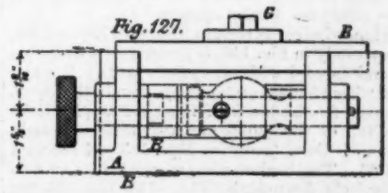












and fixture combined for the numerous holes in oil-pump bodies. It is of the type to which the term "box-fixture" or "enclosed-fixture" is given, because the article located in it is enclosed, and a cover confines it, and in this as in most instances, is also a guide for drills. This example is remarkable because of the large number of holes included. The pump body is shown in Figs. 141 to 143, subjoined. Its relation to the jig-fixture will be obvious on comparison. Its primary location in the fixture is afforded by the foot A.

The jig-fixture comprises two main portions, the body A and the hinged cover B, both being of cast-iron. The body is a rectangular frame with its feet at right angles and having various bosses for guiding the drills. It will stand upright and square on the machine table when laid on either of its faces, with one exception to be noted. This is necessary because drills have to be guided from every face. It is not bolted to the table but, being entirely self-contained, is shifted about to bring any of the bushes under the drilling spindle.

The hinged cover B, seen in Figs. 135, 136 and 138, and separately in Fig. 140, is pivoted on a hinge-pin at C and secured with an eyebolt at D. It slides closely within facings on the body, seen in the views, and carries five bushes for drilling the tapping holes in the top of the pump and two others at right angles with these (compare Figs. 135 and 136 with Fig. 142). The bushes *a a* are carried in an arm that projects downwards, Figs. 135 and 136, for drilling the plug hole, and the delivery holes in Fig. 142. The location of the hinge piece B is ensured by the pin C on which it pivots at one end, and by an abutment-piece at the other resting on an abutment in the body (see Fig. 135) where the eyebolt D secures it. The two plug holes that lie in the longitudinal axis of the pump body, Fig. 141, are drilled through bushes *b* and *c* inserted in the body of the fixture, seen in Figs. 135 and 136. These lie at a slight angle, and the opposite end *d* of the body is cut to an angle to correspond, as shown in Fig. 135. These bushes are brought up close to the faces on which the drills are to operate in order to avoid risk of spring of the tool occurring.

The location of the work is simply done. The foot A, Fig. 141, being faced, is laid on its seating *e*, Fig. 136, and the two lever-action clamps *f*, *f*, passed through slots in the body and tightened with the set screws, adjust the pump centrally. This foot, seen at A, Fig. 141, dotted, is not a permanent part of the pump. It is only cast on and faced up for holding during the various machining operations.

The last operation is to drill through the bush *c*, the drill passing through the stem of the foot which nearly separates it from the body, so that a slight tap removes the foot entirely.

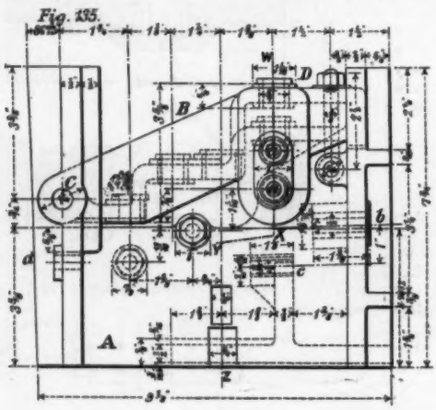
The illustrations, Figs. 144 and 145, on page 571, are those of a fixture which deals with the tooling of the bodies of feed pumps for traction engines and road rollers. The body, Figs. 146 to 149, is of the familiar form in which the ram cylinder stands at an angle with the axis of the lift valve chambers, and in which the foot lies on one side, parallel with the axis of the pump. The angle of the ram cylinder varies in different sizes of pumps for different engines. The fixture, Fig. 144, is designed to receive three sizes of pumps, the angles of which are 74 deg., 77 deg. and 78 deg., for engines of 5 h.p., 6 h.p., 7 h.p. and 8 h.p. respectively. This change is effected for two by attaching strips E, F, to the foot, E being for the 5-h.p. size, and F for the 6-h.p. and 7-h.p. The outlines of the three pumps are seen dotted in the plan view, Fig. 144, of the fixture. Each stands at 90 deg. with the foot of the fixture when the proper strip is attached to the foot. The solid foot—the one that is without the additions of either strip, coincides with the 8-h.p. pump. This terminates at the face A. If the wedge-shaped strip E is attached, this is $\frac{5}{16}$ in. thick at the thick end and is right for the 5-h.p. pump. Or if the strip F, this is $\frac{7}{8}$ in. at the thick end, and for the 6-h.p. and 7-h.p. pump body. These strips are attached each with cheese-head sunk screws as shown at G. Economies of this kind must be observed in fixture making in order to save, not only expense, but storage room.

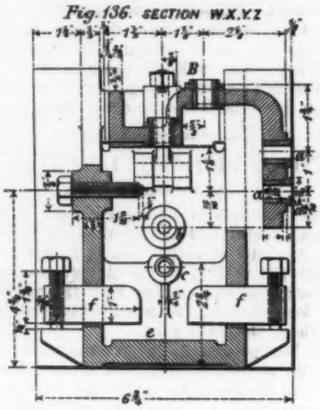
When the correct strip is affixed the pump body is put into the fixture. It is located in one position by the face of the gland-shaped flange, Fig. 144 (compare with Figs. 146 and 148), which is cleaned up to make contact with the abutment piece B, Fig. 144, cast in the fixture, against which face it is secured with the bent clamp C. Another location is afforded by the vee D, Figs. 144 and 145. Its tail being screwed, is adjusted inwards or outwards, and also locked when in position by the nuts so that the vee is not turned about. This locates the rough exterior of the cylindrical body, and accommodates itself to either body after it has been set to the correct angle.

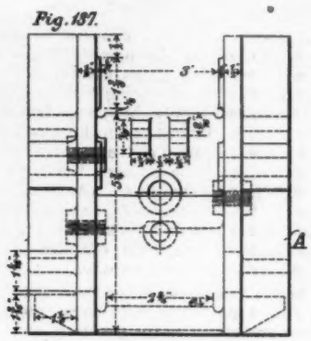
The foot by which the pump is bolted to the framing of the engine is not tooled at this stage, but is left to be planed after the exact centre of the ram has been determined by the erectors. The screws, H, H, Fig. 145, are brought in opposition to it in order to resist the pressure of the clamping plates I, I, which hold the flange down during boring. These clamps have long slot holes to render them able to cover the varied positions of the different pump bodies.

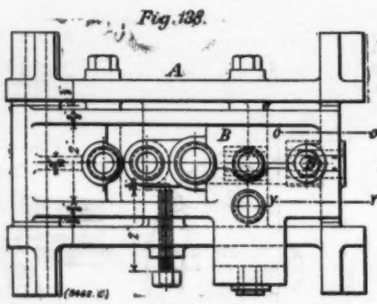
The sequence of operations is as follows: The bore for the ram is drilled and reamed, and then the gland hole is bored. The bottom valve seating is next bored, then the upper valve seating, and the recess for the cover. Finally, the bottom is faced. The tools used are shown in succeeding Figures. Each size of pump requires its own set of tools, but they are constructed similarly to those shown for one.

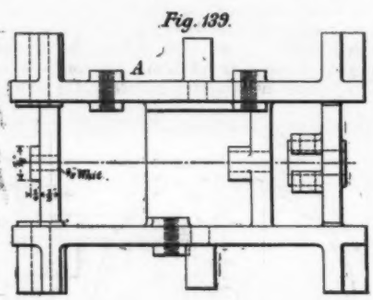
For the bore for the ram A, Fig. 146, the hole is drilled, followed by the reamer, Fig. 150, which

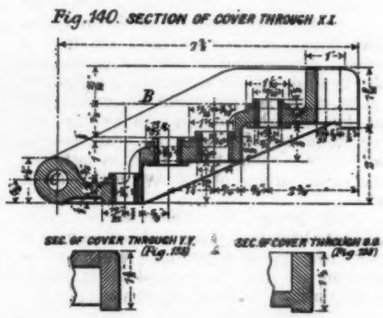


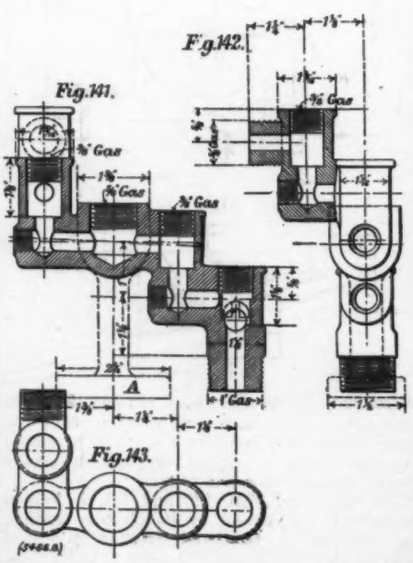








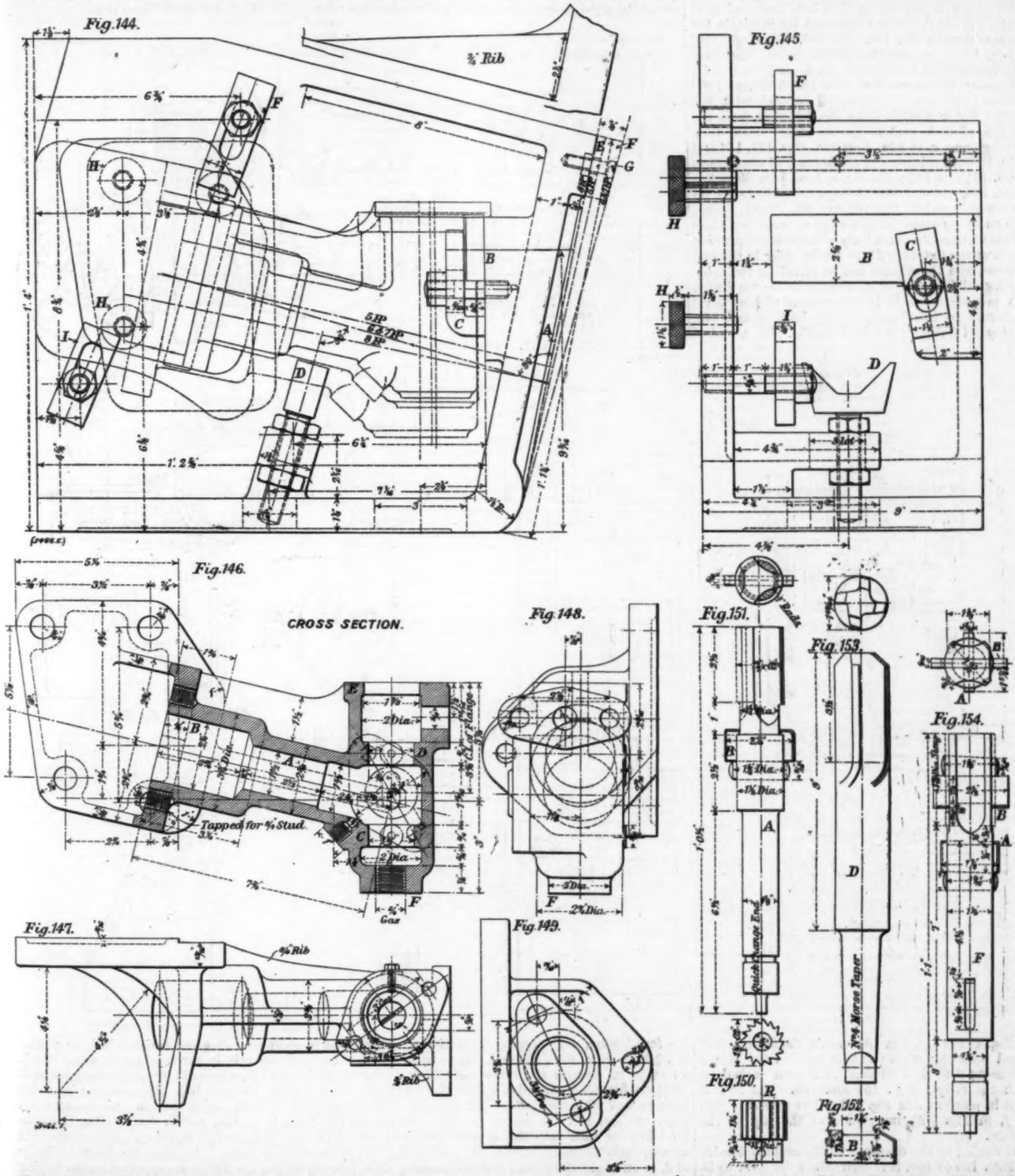




finishes it to +0·02 in. over exact size. For the 1¼-in. rams the hole is therefore 1¼ in. + 0·02 in. For the gland hole B, Fig. 146, the tool, Fig. 151, is used, taking a roughing and a finishing cut, the latter cutter, shown at Fig. 152, giving the chamfer at the termination of the bore. The bar with its cutter is guided centrally with the ram bore just finished by the pilot end, seen in Fig. 151, with three bearing edges which exactly fit the finished bore. The bottom valve seat C, Fig. 146, is drilled with the straight-flute drill, Fig. 153, followed by a reamer of the same form as Fig. 150. The upper valve seat D, Fig. 146, and the seating E for the air vessel, are done with the cutter A, Fig. 154, and the bottom face F is finished with the cutter B in the same bar.

The ingenuity of design which is embodied in some examples of jig-fixture is very noticeable. The drilling of numerous holes at right angles is a simple problem by comparison with that of drilling them at other angles. The check valve, Figs. 155 to 160, page 172, stamped in steel and having its holes and passage produced from the solid, is a case of this kind. Here are a large number of holes to be drilled in various positions, and at several angles, and all are done through a jig-fixture, Figs. 161 to 164, with the help of some loose fittings and angle-block supports. Thus, of any number of valve bodies, all will be alike.

Taking the end flanges of the check valve first. These are held centrally between the bottom of the fixture body A, Figs. 161 to 164, and the inside of the loose cover B, which cover is secured to the body with two hinged bolts, Figs. 161 to 163. The cover is shown separately by Figs. 165 and 166. The end flanges have been previously turned in the chuck, Figs. 180 to 182, to 4¼ in. diameter, and faced, and the recesses in the fixture are bored $\frac{1}{64}$ in. larger, Fig. 161, sufficient to prevent the flanges from sticking, while permitting of a



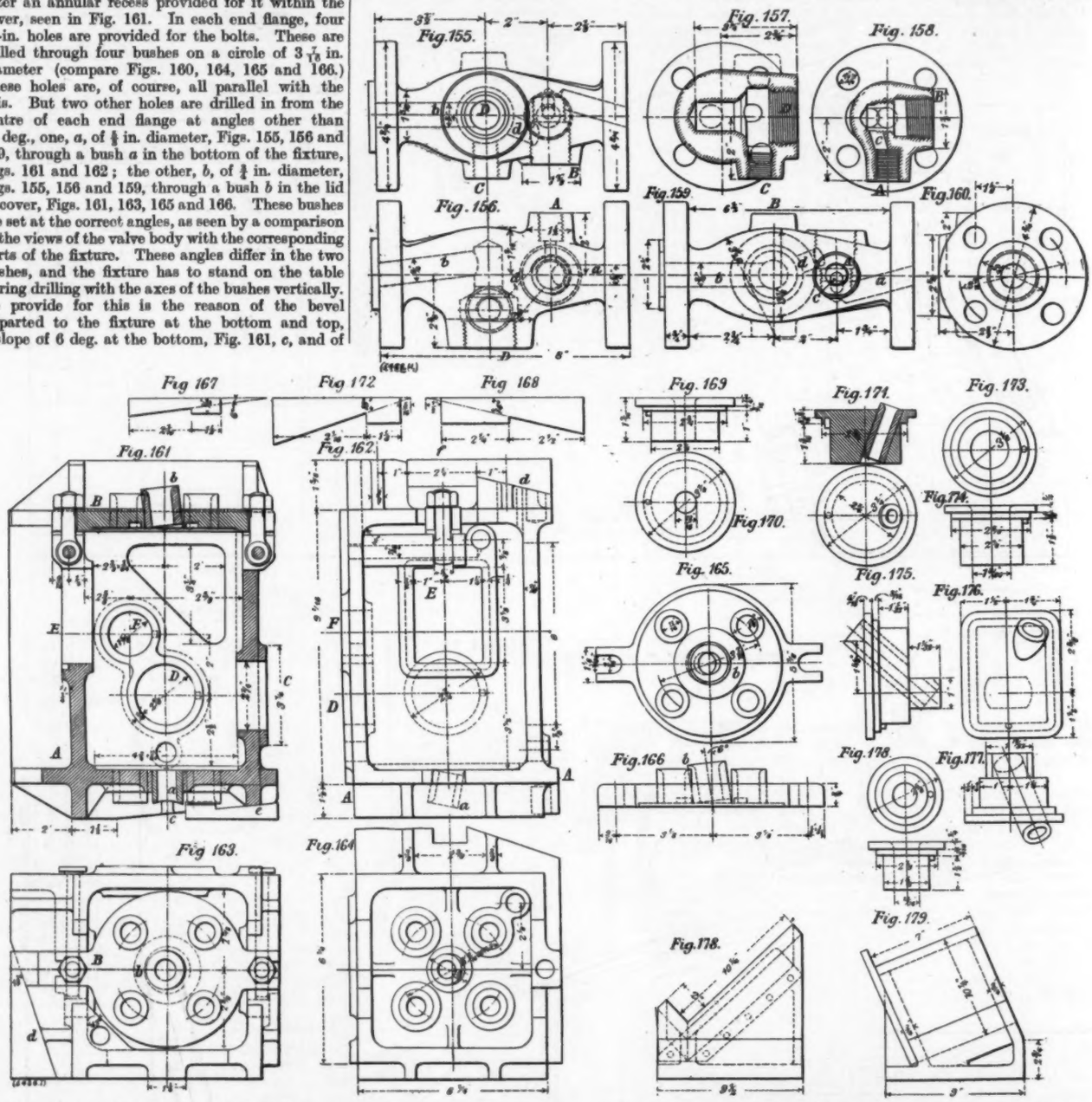
sufficiently exact location of the body in the fixture. Held thus, all the holes in both flanges are dealt with, the drill being guided by the bushes in the bottom of the fixture, and in the cover. It should be observed that the left hand end of the body in Figs. 155 and 156 is the one that comes next the cover plate. It is not possible to insert it the other way, since a register on that left hand end must enter an annular recess provided for it within the cover, seen in Fig. 161. In each end flange, four $\frac{11}{16}$-in. holes are provided for the bolts. These are drilled through four bushes on a circle of $3\frac{7}{16}$ in. diameter (compare Figs. 160, 164, 165 and 166.) These holes are, of course, all parallel with the axis. But two other holes are drilled in from the centre of each end flange at angles other than 90 deg., one, *a*, of $\frac{5}{8}$ in. diameter, Figs. 155, 156 and 159, through a bush *a* in the bottom of the fixture, Figs. 161 and 162; the other, *b*, of $\frac{3}{4}$ in. diameter, Figs. 155, 156 and 159, through a bush *b* in the lid or cover, Figs. 161, 163, 165 and 166. These bushes are set at the correct angles, as seen by a comparison of the views of the valve body with the corresponding parts of the fixture. These angles differ in the two bushes, and the fixture has to stand on the table during drilling with the axes of the bushes vertically. To provide for this is the reason of the bevel imparted to the fixture at the bottom and top, a slope of 6 deg. at the bottom, Fig. 161, *c*, and of 14 deg. at the top, Fig. 162, *d*. As the fixture must stand vertically when the bolt holes in the flanges are being drilled at 90 deg., it is then packed up with the strips, Figs. 167 and 168. The first is seen in place at *e* in Fig. 161. The second is seen at *f*, in Fig. 162, inverted over the top of the fixture.

Referring to the drawings of the combined valve in Figs. 155 to 160, it is seen that holes have to be drilled and tapped for a stop valve, a check valve, a relief valve, and for a steam whistle when such is required, which may be wanted either on one side or on the other. Also that two passage holes have to be drilled diagonally in addition to those just mentioned. These operations are provided for in the fixture by the fitting of loose bushes, which are shown in separate views.

The two bushes for drilling and tapping the hole A for the relief valve, Figs. 156, 158 and 159, are shown by Figs. 169 and 170. They both fit in the $2\frac{1}{4}$-in. hole C, Fig. 161. They are prevented from turning by a nib fitting in a notch. The bushes are of the same diameters, except for the holes that are for drilling, and tapping respectively. There is a $\frac{1}{4}$-in. hole, *c*, Figs. 158 and 159, to be drilled at an angle to connect the relief and check valves. The bush for this is carried in a disc, Fig. 171, which interchanges with the drilling and tapping bushes, Figs. 169 and 170. It lies at an angle of 18 deg. To bring its axis into the vertical position, the opposite side of the fixture is cut away, Fig. 163 at *d*, to an angle of 18 deg., and the packing piece, seen also at *d* and shown separately in Fig. 172, restores the fixture to the correct position for drilling holes square through with the axis of the work.

For the check valve at B, Figs. 155 and 158, four bushes are used, Figs. 173 and 174, which fit in the $2\frac{1}{8}$-in. hole, Figs, 161 and 162, D, in the fixture, being prevented from turning by the nib and notch. These bushes guide in succession the tapping drill and the tap for the $\frac{3}{4}$-in. gas thread at the bottom, followed by the larger similar bushes for the 1-in. gas thread at the top.

There is a $\frac{1}{4}$-in. hole, *d*, Figs. 155, 156 and 159, to be drilled from the check valve to the stop valve, and it occupies a diagonal position in both planes. The bush for this is carried in a locating block, Figs. 175 to 177, which fits into the oblong recess E seen in Figs. 161 and 162. The nib and its notch prevents it from being put in the wrong way. The bush is carried within the casting close up to the face to be drilled in order to prevent the drill from slipping aside. To bring the bush vertically during drilling the fixture is supported on the sloping face of an angle bracket, Figs. 178 and 179. It provides for the angles of 15 deg., in one direction, and of 37 deg. in the other (compare with those angles of the bush in Figs. 175 to 177). The bushes for the whistle at C, Figs. 155 and 157, are seen in Figs. 178 and 179, one being for drilling the tapping



hole, the other for guiding the tap. These fit in the 1¼-in. hole F, Figs. 161 and 162.

The hole D for the stop valve, Figs. 155 to 157, is done in the lathe when the end flanges are faced. The article is held in the chuck, Figs. 180 to 182, being clamped in blocks located in each of the three positions required, by means of the pin and bushes shown. The main bracket-piece A, of the chuck, fits the lathe with a spigot. A horizontal flange

Fig. 180.

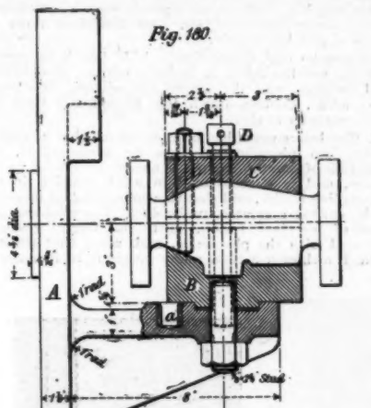


Fig. 181.

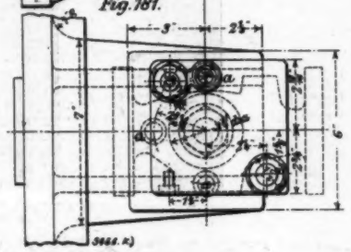


Fig. 182.

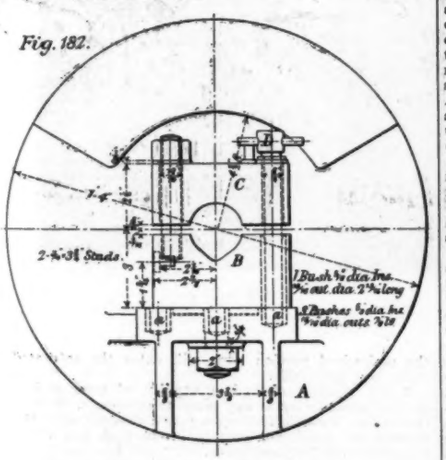
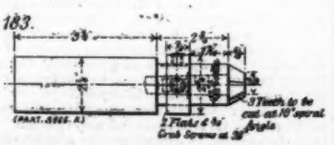


Fig. 183.



carries one chucking block B, cut to the contour of the body of the valve, and fitting to the flange with a spigot on which it is rotated to present the three flanges in succession to be faced and turned. Another chucking block C clamps the valve from above. The three positions for the flanges are located by the three steel bushes *a*, *a*, *a*, driven into the horizontal flange of the bracket. Their plan relations are seen in Fig. 181. A long pin D is thrust through the upper and lower chucking blocks to enter into these bushes in turn, which pin fits the long bushes seen in Fig. 182 to counteract the effects of wear. A stud with its nut clamps the lower chucking block to its plate, and another secures the upper block to the lower with the valve body between them. The eccentric fitting of the chuck entails the employment of a counterbalance on the plate, seen in Figs. 180, 181 and 182. The tool used for seating is seen in Fig. 183, which may be compared with the section of the hole in Fig. 157. A collar gauges the depth of the seating. The tools for boring and recessing are not shown.

IRON, CARBON AND PHOSPHORUS.*

By DR. J. E. STEAD, F.R.S., Vice-President.

THIS short paper may be taken as Part II of the paper read before this Institute in 1915† and will be treated in two sections :—

SECTION I.—The effect of introducing carbon, by cementation, into homogeneous solid solutions of iron and phosphorus.

SECTION II.—The temperature ranges in which free phosphide of iron passes in and out of solid solution in iron.

SECTION I.

It has been proved that when alloys of iron, carbon, and phosphorus are heated to the point of incipient fusion, the phosphorus and carbon become concentrated in the part that first becomes liquid. On the other hand, it is well known that if the same alloys after complete fusion are gradually allowed to solidify, the last portion to become solid contains much more carbon and phosphorus than the parts which first solidified.

It has been shown by Professor Arnold and others that alloys containing traces up to 1·36 per cent. phosphorus and practically no carbon, when allowed to solidify and cool, contain all the phosphorus in solid solution, and that if the carbon is gradually increased in the liquid metal, after solidification it contains more and more free phosphide of iron, and that when a maximum amount of carbon is present the greater part of the phosphide exists in the free state in a eutectic mixture. It follows, of course, that if the metal contains just sufficient carbon short of that required to lead to the separation of a eutectic, the last portion to freeze may be a saturated solution containing about 2 per cent. phosphorus and will contain no phosphide in the free state.

It has further been proved that when a steel of medium carbon content becomes completely solid and is then slowly cooled, the portions richest in phosphorus are quite free from carbon, although it is known that the two elements must have been in association at the point of solidification of the steel. The reason for this appears to be that the solid solution pressure of carbide and phosphide together is considerable, and that as the carbide is very mobile, whilst phosphide is less so, the carbide simply moves into the surrounding metal where the solution pressure is feeble—that is to say, into and near to the primary crystals, which first fell out of solution, and which contain less phosphides and carbides. As cooling progresses, the carbide in solid solution steadily flows towards the purer portions, concentrates there, and finally separates as free carbide of iron (Fe_3C) in pearlite.

The phosphide, which, like the carbon, is still in tension in the areas vacated by the carbon, slowly flows outwards into the regions where the internal tension is lower, but, as the temperature falls, its power to move becomes less and less, and at about 800 deg. C. becomes exceedingly sluggish, and at 500 deg. C. it is practically stagnant.

Distribution of Phosphorus in a Cast Alloy.—This note, as will be seen later, shows how wonderfully excursive phosphide in solid solution in iron really is. It leads one to believe that when the relations of iron, iron phosphide and carbon are better understood, it may be possible to control the effect of phosphorus on the physical properties of steel.

The fact that prominent metallurgists refer to phosphorus as treacherous is clear proof that the reason for its variable effect is not known. But for the knowledge gained by years of research on the influence of carbon on iron, that element probably would be considered even more treacherous than phosphorus. We have gained knowledge, and now know how to control the effect of carbon.

The series of six photographs (page 574) of an alloy in the cast condition, containing about 0·3 per cent. carbon and 0·3 per cent. phosphorus, after etching by different reagents, clearly shows where the phosphorus is concentrated. The first three were taken from the same area, but were etched in different ways :—

No. 1 was etched by alcoholic nitric acid, and shows simply the pearlite areas (dark) and ferrite (white).

No. 2 is the same as No. 1, after an attack by the author's cupric reagent, but only the phospho-ferrite and the carbide of the pearlite remain white.

The ferrite of the pearlite and the ferrite surrounding the pearlite areas have been stained by the cupric reagent, which is an indication of relatively low phosphorus.

No. 3. After repolishing and attacking by picric acid in water the parts rich in phosphorus are stained quite black, but do not correspond exactly with the white areas in No. 2; they are included in it, but are very rich in phosphorus.

No. 4 is a part of the same steel; it was heated to 960 deg. C. and quenched in water, and etched with nitric acid in alcohol. It shows that the carbon has not diffused into that part of the ferrite which is highest in phosphorus, but has invaded the part containing less.

No. 5 is the same area as No. 4, after repolishing and etching with a cupric reagent. It shows that although the carbon has diffused into the parts lower in phosphorus, the phosphorus has not moved.

No. 6 is the same area as Nos. 4 and 5, after repolishing and etching with aqueous picric-acid solution. The parts of the ferrite richest in phosphorus are darkened, and on comparing these darkened areas with the white areas in No. 4 it will be noticed that they correspond exactly in shape and volume.

By heating to 960 deg. C. the carbon has been forced to invade the parts of the ferrite less phosphorised, but on slow cooling it returns to the parts still lower in phosphorus, leaving them free from carbon. If the cooling is effected in about 5 minutes, the pearlite does not concentrate in the original position, but remains distributed in small separate grains in the areas proved to be lower in phosphorus, which includes the areas occupied by the original pearlite and the ferrite envelopes. When, however, the alloy is heated to 1,200 deg. C. and slowly cooled to 500 deg. C. in a period of three to four days, the phosphorus is found to be more homogeneously distributed, and the cold steel then has a structure approximating to that of a normal steel containing the same amount of carbon. (See note on "Inclusions in Steel.") The long heating at above 1,200 deg. C. allows the two elements time to become interdiffused, and in cooling no separation is effected. All rolled steels containing phosphorus ghost-lines, after long heating to above 1,200 deg. C., are homogeneous, and phosphorus lines no longer appear on etching the cold steel.

Effect of Introducing Carbon by Cementation.—Judging from the foregoing remarks, it would appear that the solution pressure of the carbon very greatly increases with the temperature, and that phosphide of iron, although less rapid in its movement than carbon, is very excursive; indeed, when it is irregularly distributed in iron, the phosphide in the parts richest in phosphorus at high temperatures diffuses into the parts containing less, and in time perfect homogeneity is produced.

Now on these bases it seemed certain, if an alloy containing phosphorus homogeneously distributed is carburised at a high temperature, that as the carbon passes into solid solution the internal tension will be increased, for, to the tension of the phosphorus will be added that of the entering carbon. Under such a condition one would expect that as the carbon enters, the phosphorus would be forced to move out of the areas invaded by the carbon and become concentrated in the surrounding metal, and that this concentration would proceed until the increased tension of the phosphide in solid solution balanced the tension of the carbide in solid solution. Theoretically then, if the temperature is below that of the formation point of the ternary eutectic Fe–C–P, eventually no more carbon could enter into solid solution, and that would be when the tension in the territory held by the carbon is equal to that in the parts where the phosphide is concentrated. To what extent the Fe_3P can be concentrated in that way is not known, but it is probable it would approach the point of saturation, or 14 per cent. = 2 per cent. phosphorus.

To determine whether this hypothesis was correct or not, the following experiment was made :—

An alloy containing about 0·5 per cent. phosphorus in homogeneous solid solution, but quite free from carbon, in the form of a short bar 1½ in. by 1 in. by ½ in., was sawn vertically through its centre, thus making two bars 1½ in. by ½ in. by ¼ in. The sawn faces were placed in juxtaposition, and the lower ends placed on a bed of charcoal at the bottom of a plumbago crucible. They were surrounded and covered by sand and a lid luted on to the crucible. The crucible, with contents, was then placed in a muffle furnace having a temperature of 960 deg. C., and retained in that position of 6 hours, and was then heated to 1,150 deg. for 1 hour in a separate furnace. The crucible was removed and one of the bars was quenched in cold water, the other was allowed to cool down slowly in the crucible. By this means one obtained in the quenched bar martensite areas corresponding exactly with parts into which carbon had penetrated, whilst in the bar slowly cooled one obtained pearlite islands in ferrite, into which the diffused carbides had condensed or segregated from the parts invaded by it.

The juxtaposed faces of the bars were polished and etched by various reagents, and photographed. The photo prints are shown in page 575.

No. 7 is a photograph of the bar itself after a strong attack by a cupric reagent. Note that the carburised end is dark, while the other is light.

No. 8 represents the structure of the specimen quenched from 1,150 deg. C. at a point where there was only about 0·20 per cent. carbon. Etched with acid.

No. 9 is the same area as No. 10 etched by the cupric reagent.

No. 10 represents the slowly-cooled bar at an area corresponding to No. 8 etched by acid, which left the carbide areas as pearlite (dark) on a white ground.

No. 10A represents the most carburised part of the cemented bar etched by acid, after quenching from 1,150 deg. C. Magnified by 100.

These illustrations are most instructive and prove the correctness of the hypotheses advanced, but are also suggestive as to the way in which the carbon enters the central portions of the bars.

On examining the photographs Nos. 8 and 9, it will be noticed that in each one the dark areas are islands quite isolated from one another, and are completely surrounded by ferrite. It is obvious then that the carbon has not entered the metal directly from the charcoal cementing material, for if it had there would have been a continuous

* Paper taken as read before the Iron and Steel Institute on May 3, 1918.

† Journal of the Iron and Steel Institute, 1915, No. 1, page 140. ENGINEERING, May 21 and 28 and June 4, 1915.

track of martensite leading from the exterior to the interior of the quenched bar.

A son of the author (the late Lieutenant J. K. Stead), in a research he made on the question of carburisation, found that if pure iron or soft steels were covered with a porous layer of magnesia, lime, or asbestos, and were cemented alongside duplicates of the same metals with bare surfaces under identical conditions, the carburisation was equal in each set of cases, yet in one the charcoal was in direct contact, while in the others the iron was separated from it by porous coverings. Obviously, then, the carbon did not combine directly with the metal.

Evidence is conclusive that metals at high temperatures are quite porous to gas (carbon monoxide), and it is this gas continuously produced in the cementation furnace that effects carburisation; indeed, it is quite easy to carburise iron by carbon monoxide alone without the presence of any solid carbon. A cementation furnace, therefore, may be considered simply as a carbon monoxide gas producer, and one in which the carbonic acid, produced in the carburised metal after it diffuses out, is regenerated. The reactions are, of course, well known and may be briefly described.

Carbon monoxide is primarily produced by the combination of oxygen of the air mechanically associated with the charcoal and the carbon of the charcoal. This carbon monoxide penetrates the metal, and gives up a small part of the carbon to the iron, but the oxygen of the decomposed carbon monoxide combines with a portion of the excess carbon monoxide gas, forming carbon dioxide. The carbon dioxide tends to oxidise carbon at high temperatures, and can only be formed in such proportions as to establish equilibrium with the remaining carbon monoxide so as to produce an inert mixture. When this point is arrived at, the mixture diffuses out of the metal and comes into contact with the charcoal, which at once removes half the oxygen from the carbon dioxide, producing in its place double its volume of carbon monoxide. The cycle is then complete and is continuously repeated.

When pure iron is cemented, as a rule the carburised areas are continuous when the metal is in a heated state, the parts nearest the outside being always richest in carbon. On quenching such carburised iron directly it leaves the furnace, the martensite forms an almost connected layer from the outside to the extreme point to which the carbon has penetrated. There can be little doubt that the greater solution pressure of the carbide on the outer layers leads to diffusion towards the centre of the bars, for on heating superficially carburised iron in vacuum to a high temperature, the carbide does diffuse inwards. Although carburisation of iron is effected by charcoal in the manner described, it must not be assumed that iron and carbon cannot directly combine without a gaseous vehicle, for Sir W. Roberts-Austen long ago obtained direct union by heating a diamond *in vacuo* in contact with iron. It is well known also that free graphite locked up in grey pig-iron combines directly with the iron surrounding it on heating to a point short of fusion.

An interesting experiment with a piece of a bear from a Wigan blast furnace demonstrated the same thing. The specimen contained more than 1 per cent. of phosphorus in solid solution, and spheroidal segregations of graphite distributed at wide intervals, and only traces of pearlite. A portion of this was heated to about 1,300 deg. C. for about 10 minutes; it was then quenched at once in water. On sectioning the quenched material, polishing and etching with an acid, and then with a cupric reagent, the evidence was conclusive that not only had the carbon combined directly with the iron, but had diffused into the surrounding metal, and in doing so had caused the phosphide to pass out of solid solution and unite with some of the carbide to form the liquid ternary eutectic which first appeared at the crystal junctions and later as liquid globules, which by coalescence with other globules eventually reached the junctions of the iron carbon crystals, and flowed along these back into the place originally occupied by the graphite.

Having explained the general principles underlying normal carburisation, return must be made to the cemented phosphoretic iron. In this, excepting at the surface most highly carburised, the penetration is not continuous, and in the centre of the quenched bar, as before stated, the carburised portions are completely surrounded by ferrite. One can only advance hypotheses to account for this, and assume that the metal was not absolutely homogeneous, and that carbon was first deposited in the portions containing a slight excess of iron or a slightly less amount of phosphorus. From the very start, as was proved, the carburised areas are isolated even where the metal was in contact with the charcoal, and these develop more or less radially with the progress of cementing. Proof that as the carbon enters it causes the phosphorus to diffuse away from it is given in photograph No. 11, of a few minute areas, highly magnified, where carburisation had just commenced. The specimen was quenched and etched first with acid and then with a cupric reagent. The dark martensite is surrounded by a white envelope which is higher in phosphorus than the metal exterior to it. A part of the phosphorus has been forced into that position by the dominating solution pressure of the carbon.

That the phosphorus is generally concentrated in the ferrite, owing to carbon penetration, is proved by the photograph of the whole bar after it was polished and then etched with copper solution, for the end where carbon penetrated is only slightly stained, while the other end is almost dark, due to a greater deposit of copper. Copper is only deposited on the parts where phosphide in solid solution is small, refusing, in the same period of time, to deposit where it is greater.

The evidence that the areas invaded by the carbon surrounding the pearlite are very low in phosphorus is given in the photograph No. 8 of the annealed specimen after etching with the cupric reagent. It will be noticed that the areas of martensite in the corresponding quenched specimen have about the same superficial area as the half-tone envelopes and the pearlite together of the slowly cooled metal.

It is evident that once the carbon has entered at several independent adjacent points, the phosphorus in the surrounding ferrite is increased and the solution pressure or tension, being also increased, must tend to check the ability for external carbon to enter it. That such is the case was proved by cementing thin plates of metal of the same size and thickness but containing varying proportions of phosphorus. The results were as follows:—

	Carbon Absorbed. Per Cent.
Iron alloyed with 1·2 per cent. phosphorus...	0·53
Iron alloyed with 0·6 per cent. phosphorus...	0·60
Pure electrolytic iron—nil	0·94

The carbons were determined by the colour method, as the weights of the minute plates were insufficient to make combustion analyses, and therefore must be regarded as relative only.

Summaries and Conclusions.—1. It has been proved that the pearlite areas in medium carbon phosphoretic steel castings, and the ferrite immediately enveloping those areas, contain much less phosphorus than the ferrite exterior to them.

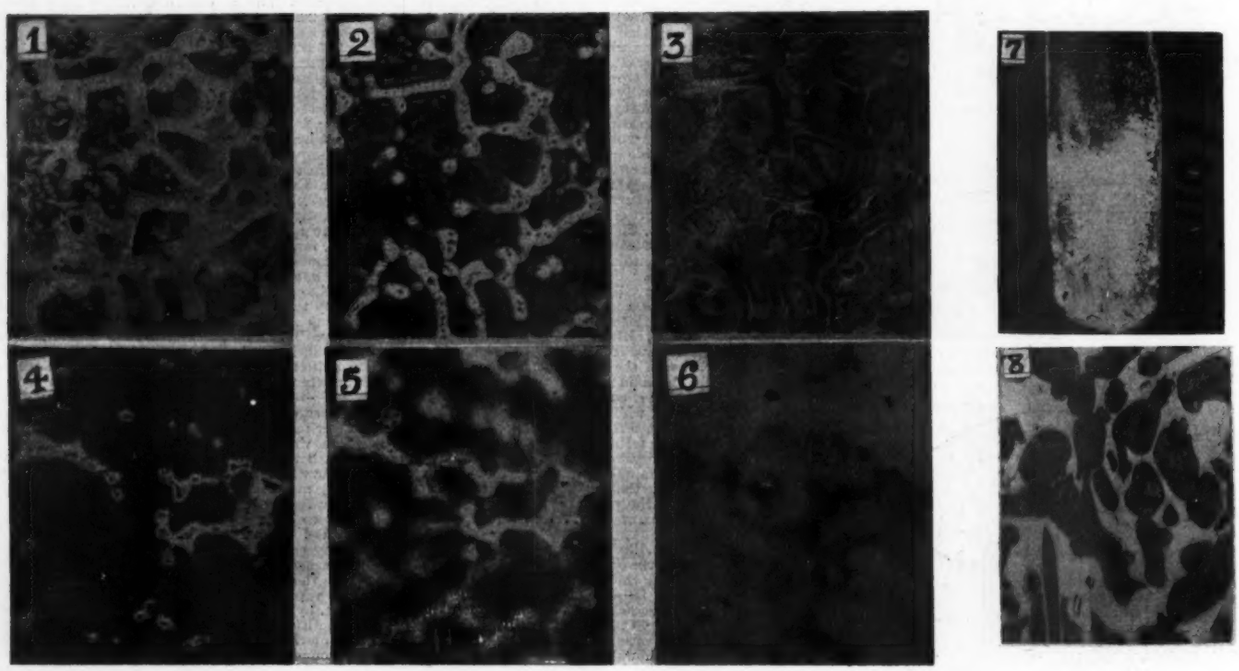
2. Conclusive proof has been advanced that as carbon enters into phosphorised iron by cementation, the phosphide of iron diffuses out of the areas invaded by the carbon, and is concentrated in solid solution in the surrounding ferrite, and that this concentration increases as the carbon increases, probably at temperatures just short of incipient fusion, until the ferrite becomes saturated with the phosphide, and, when that point is reached, although carbon many continue to increase in the carburised portion none will enter the saturated solution of phosphide.

3. The amount of carbon capable of passing into iron by cementation at any given temperature, short of the ternary eutectic formation point, depends upon the amount of phosphorus present in the iron and varies inversely with the phosphorus.

If the temperature of the cementation furnace exceeds the formation point of the liquid ternary eutectic, the internal tension in the ferrite rich in phosphorus, due to the continued increasing external tension of the invading carbon, at last becomes so great that the phosphide is forced out of solid solution in the very centre of the ferrite, forming a eutectic liquid.

5. It is confirmed that graphite can carburise iron without the interposition of any gaseous vehicle, and that the carbon, in diffusing from graphite nuclei bedded in iron containing phosphide in solid solution, behaves in a similar way to carbon from carbon monoxide: it concentrates the phosphide in the ferrite and eventually at 1,200 deg. to 1,300 deg. C. throws it out of the solid into the liquid solution, producing the ternary eutectic Fe–C–P, which appears in the globular form and as intercrystalline envelopes, and finally liquates out of the metal.

6. The research opens the door for more investigation. The specimens experimented upon were very high in phosphorus, much higher than is permissible in any steel. It is proposed to make further trials with steels containing variable quantities of that element within the limits of 0·12 per cent. and 0·02 per cent., when associated with between 0·1 per cent. and 1 per cent. carbon.



NOS. 7 AND 8. REDUCED BY ONE-QUARTER.

SECTION II.

The Temperature Ranges at which Iron Phosphide

passes in and out of Solid Solution in Iron.—When this investigation commenced it was thought that the ranges of temperature at which phosphide of iron (Fe_3P) passed in and out of solid solution in iron would be as readily determined as the critical ranges at which carbide of iron passes in and out of pure iron, but instead it was discovered that, owing to the more inert character of the phosphide, such was not the case. It was found that years of careful research would be necessary before complete knowledge could be obtained.

The records which follow must be regarded as the result of a reconnaissance and scouting expedition into an almost entirely new, unexplored country, but nevertheless contain sufficient evidence to enable any one more systematically to carry on future work. The importance of what has been done, however, will be recognised when it is seen that there are indications that similar laws govern the solid solution and dissolution of solids in solids as those which govern the solution and dissolution of crystalline salts in liquids.

The illustrations, with descriptions, enable one to see at once the proofs of solution and dissolution. This has only been possible because during the past few years greatly improved methods of etching and staining the complex mixtures have been evolved.

What little work that has been done in the past on the crystallisation of Fe_3P from solid solution is recorded in various papers by the author, and the first indication or evidence of the temperature at which free phosphide could be induced so to crystallise was published in the Journal of the Iron and Steel Institute in 1890, in which it was noted that on exceedingly slow cooling from above 1,200 deg. C. of an alloy containing about 2 per cent. phosphorus and 0·12 per cent. carbon, free phosphide of iron separated out between some of the cleavages of the iron crystals. The alloy in question was made by melting puddled iron with phosphorus in a clay crucible.

After melting, the crucible and contents were allowed to cool slowly in the fire; the time of cooling to 500 deg. C. was estimated at about 6 hours. As no free independent phosphide of iron (Fe_3P) crystals were present in the original alloy, it was assumed that the time occupied in cooling through the critical range in the crucible furnace was not sufficient to admit of the crystallisation of that body from solid solution. On reheating to between 1,200 deg. and 1,300 deg. C. in a 3-ton ladle of molten blast-furnace slag and allowing the alloy and the slag to cool down together in about four or five days, free crystals appeared—proof that long cooling through the critical range, whatever that may be, was sufficient to admit of some of the phosphide of iron crystallising out. Particulars are now given of the most recent investigations in that connection.

Alloys Used in Experiments.—A series of alloys was selected, on which to experiment, including :—

Series I.—A decarburised alloy from a Cleveland blast-furnace bear referred to in another paper on "Blast-Furnace Bears," which, although variable in different parts, contained free phosphide in envelopes round the crystals of iron and free Fe_3P in the body of the metal. The analyses varied between :—

	1. Per Cent.	2. Per Cent.
Phosphorus in solid solution	0·50	0·623
Phosphorus in the free phosphide	0·40	0·883
Total	0·90	1·506

Series II.—A Mexican meteorite containing rhabdite or free phosphide crystals.

Series III.—Alloy of iron and phosphorus made by adding phosphorus to white-hot puddled bar in a clay crucible. It contained :—

	Per Cent.
Phosphorus in solid solution	1·16
Phosphorus in eutectic...	0·04
Total	1·20
Carbon	0·12

Series IV.—A series of alloys containing between 0·4 per cent. and 2·2 per cent. phosphorus made by the thermit process. These contained rather variable amounts of silicon, aluminium, &c., approximating on an average to :—

	Per Cent.
Carbon	0·05
Manganese	0·10
Sulphur	0·04
Silicon	0·15
Aluminium	0·12
Phosphorus	0·4 to 2·2

Series V.—Portions of the Cleveland decarburised bear free from independent phosphide of iron (Fe_3P) containing only traces of carbon and between 0·5 per cent. and 0·60 per cent. phosphorus in solid solution.

SERIES I.

Temperature at which the Phosphide of Iron passes into Solid Solution.—The first trials were made on the decarburised bear referred to, containing :—

	Per Cent.
Phosphorus as free phosphide of iron (Fe_3P)	0·70
Phosphorus in solid solution	0·55
Total phosphorus	1·25

After making a large number of trials by heating at various temperatures over long periods extending from 6 hours to 28 hours, it was found that whilst none passed into solution at 800 deg. C., at 850 deg. C. solution commenced. It may be expected, therefore, that with a solvent containing about 0·5 per cent. phosphorus, phosphide commences to dissolve at some point between 800 deg. and 850 deg. C.

On heating to 960 deg. C. solution proceeds with considerable rapidity.

On examining Photographs 20 to 23 the progress of solution will be seen. In 5 minutes it is considerable, in 15 minutes it is nearly complete.

On long heating at 1,000 deg. C. the diffusion is perfect and the alloy homogeneous, for sections of the metal after polishing and etching with a cupric reagent show no dark and light-coloured places.

SERIES II.

In the last series the solvent metal contained a considerable quantity of phosphide in solid solution, and it was naturally believed that it would not dissolve phosphide so readily as pure iron free from phosphorus.

Having a specimen of a Mexican meteorite containing free crystals of iron nickel phosphide, or rhabdite, containing :—

	Per Cent.
Phosphorus in solid solution	0·21
Phosphorus in phosphides	0·06

trials were made with it to find out at what temperature the crystals began to dissolve.

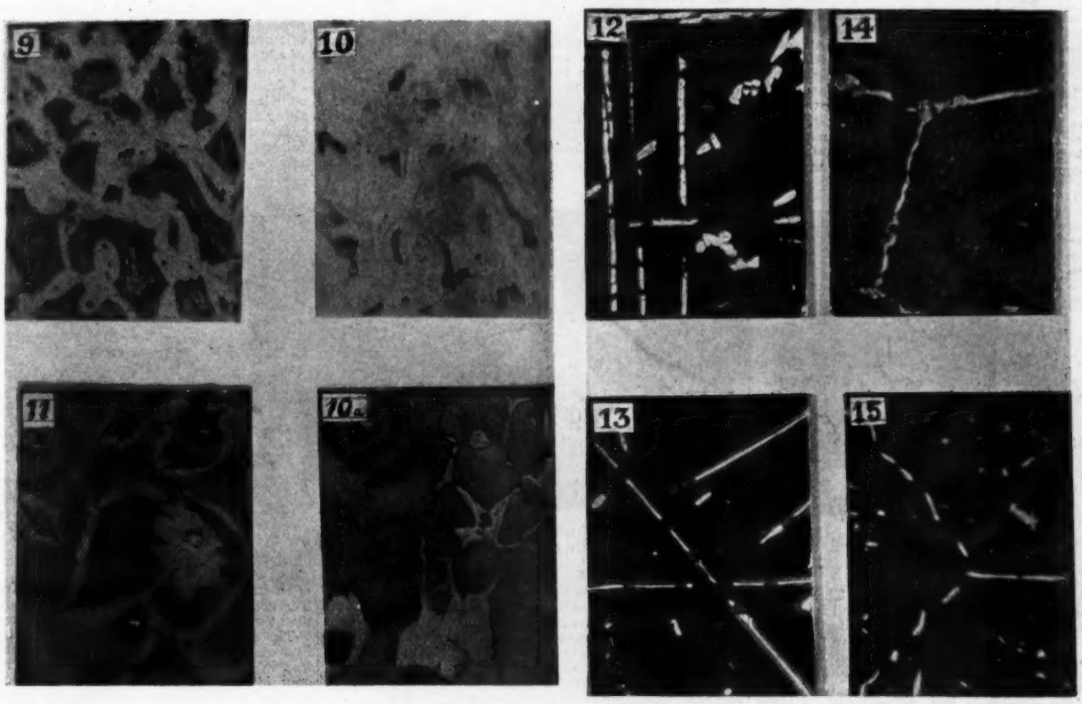
Of course there is objection to using a nickel iron alloy containing about 5 per cent. nickel, and rhabdite, which contains much more nickel than the matrix, and one could not infer that it would behave in the same way as an alloy free from nickel. Whether that is so or not, it is of interest to find out how it did behave. Without going into detail, it is sufficient to say that the rhabdite began to dissolve at about 600 deg. C. on heating for 12 hours, proving that solution begins at a relatively low temperature as compared with the iron alloy. As the heat is raised solution is, of course, very pronounced and rapid.

There were certain phenomena connected with the heating of this alloy which cannot at present be explained. It is reserved for further investigation.

Not having any pure iron with free phosphide of iron crystals in it, and no phosphide in solid solution, an attempt was made to make a mechanical mixture of iron and phosphide crystals. For this purpose a minute hole was bored into piece of Armco iron containing 99·8 per cent. iron. A few crystals of iron phosphide were placed into the borehole. (The iron phosphide crystals were obtained from the Cleveland bear already referred to.) A plug of the same iron was then driven into the hole, and the bar was flattened cold under a steam forge hammer, which, of course, forced in the sides of the hole against the phosphide. The bar was then heated to 700 deg. C. for 3 hours, after which it was sectioned and examined. The sides had not welded together where they came into contact, but at points there was distinct evidence that the phosphide had commenced to dissolve in the iron. This experiment is to be repeated and the period of heating prolonged at a lower temperature. It proves, however, that while the same phosphide does not dissolve in iron partially saturated with phosphide in solution, it does dissolve in iron free from phosphorus at 700 deg. C.

SERIES III.

To Determine at what Temperature Phosphide falls out of Solution.—In this set of trials a bar ½ in. square and 4 in. in length was bedded in mill scale contained in a porcelain tube closed at one end. The closed end was



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inserted through a hole in the side of a muffle furnace which was heated to a temperature of 1,000 deg. C. each day during 6 hours. The hot end of the bar was actually heated to the point at which silver wire just melts, while the other end, which protruded out of the muffle furnace, never attained a temperature above 500 deg. C. It was heated intermittently for 60 hours and then removed from the furnace and examined. The temperature at each point along the bar, when at maximum temperature, was taken at intervals and the positions noted. The bar was ground down on one side, and, after polishing, was etched and examined under the microscope. Before describing the observations it is necessary to explain that, as the bar contained some carbon, it was thought desirable to remove it if possible, at least in the parts where it was heated above 800 deg. C., hence the object of bedding it in mill scale.

Like all cast alloys of iron and phosphorus, the phosphorus was not uniformly distributed. It contained traces of the eutectic Fe–P, and at places adjoining these, the alloy must have been a saturated solution of iron and phosphide containing about 2 per cent. phosphorus. As it contained patches of pearlite at intervals bedded in the parts containing least phosphorus, from actual trial it is known that the territory covered by this pearlite contained much less phosphorus than the average in the whole metal. There were, in fact, parts very rich, parts less rich, and parts poor in that element and therefore in the one alloy a series of three distinct alloys.

On examination after heating it was found that in the parts most highly charged with phosphorus, free crystals of iron phosphide (Fe_3P) were present at all places where the temperature exceeded 660 deg. C. up to 900 deg. C. The crystals were exceedingly minute where they had formed at the lower temperature, but increased in size as the temperature rose, and were at a maximum at 900 deg. C. At about 800 deg. to 850 deg. C. the amount crystallised out was at a maximum, but at 800 deg. C. no crystals could be detected in areas originally occupied by the pearlite, which were now completely decarburised by the mill scale. These areas, of course, contained the least phosphide in solid solution. Where the metal had been heated at 900 deg. C. only in the metal adjoining the eutectic films were there any free crystals, and at 960 deg. C. there were none. The metal at that temperature had become a homogeneous solid solution. There were no eutectic films, for, presumably, the phosphide had diffused out of them and passed into solid solution at such a high temperature as 960 deg. C.

These observations show clearly that the temperature at which phosphide of iron (Fe_3P) falls out of solid solution depends upon the amount present.

SERIES IV.

In this series the thermit metals were employed, and, in passing, it is important to note the original structures of the cast alloys.

All of them when etched with a cupric reagent became rapidly coloured on the parts which had first fallen out of solution. The dark markings were in the form of octahedral skeletons very clearly marked on polished cleavage faces. In addition to these, in the alloys containing between 0·9 per cent. and 2·2 per cent. phosphorus there were present trains of the binary eutectic of iron and phosphorus on all the sides of the dark-stained primary crystallites.

They were all heated in a muffle furnace for 6 hours at 1,000 deg. C. and then re-examined. As was expected, such treatment led to the diffusion of phosphide and iron. The primary crystallites no longer were in evidence, and excepting in the alloys containing more than 2 per cent. phosphorus, the eutectic had also vanished and the metals had become homogeneous solid solutions.

What is most remarkable is that on reheating the alloy containing 2·2 per cent. phosphorus to 1,050 deg. C. for a short time in an attempt to get more of the eutectic dissolved, and then for a longer time at between 960 deg. and 1,000 deg. C., a crop of minute iron phosphide (Fe_3P) crystals appeared. Possibly at the higher temperature the iron had become supersaturated and on heating to the lower temperature the excess fell out of solution. (See Photograph No. 17.)

On reheating this same specimen for 6 hours at 800 deg. to 840 deg. C. the crystallites developed to a considerable extent, as will be seen in photograph No. 18, below.

Another specimen, containing close on 2 per cent. phosphorus, heated to 1,000 deg. C. had no free crystals, but contained some undissolved eutectic. On heating at 820 deg. to 840 deg. C. for 6 hours new crystals developed freely. (No. 19, below.) Probably this would have yielded crystals at 900 deg. to 960 deg. C., but the experiment was not made owing to want of time.

SERIES V.

In this series sections were used cut through three columnar crystals of the Cleveland decarburised bear. One containing a total of 1·25 per cent. phosphorus was heated to 960 deg. C. for 10 minutes, when it was found that practically all the free phosphide had dissolved, but was concentrated in solid solution around the traces of undissolved phosphide. It was then heated for several hours at 780 deg. to 800 deg. C., after which treatment it was proved that some phosphide had recrystallised round the original traces of the free phosphide. The specimens before and after the treatment are shown in Photographs Nos. 14 and 15.

Another section was heated to 1,000 deg. to 1,050 deg. C. to produce a homogeneous alloy. It was then reheated for 6 hours at 820 deg. to 840 deg. C. Fine crystals formed at the junctions of the crystals and near to the junctions. The evidence here is that when pre-existing free phosphide exists, on heating to a temperature favourable for crystallisation the phosphide is primarily attracted to it.

It will be noticed in photographs Nos. 14, 15, 17, 18, 19, that round about the larger masses of free iron phosphide there are borders containing practically no crystals, presumably because the enveloping layers of phosphide had been first formed and had attracted the phosphide from the metal near them before the temperature fell low enough for the crystals to form in the body of the metal.

Analogy between Liquid and Solid Solution and General Conclusions.—Iron phosphide is a chemical salt, for, in its formation, when iron and phosphorus are brought together at a temperature of 1,000 deg. C., or above, chemical union is effected and is accompanied by considerable rise of temperature. There seems little doubt that it retains its identity after it dissolves in solid iron.

The following facts relating to one of the most simple salts—sodium chloride in water—will enable one to compare them with the evidence advanced about the solution of iron phosphide in iron.

The point at which salt and water become saturated in any range of temperature is one of equilibrium. Water can be saturated in a wide range of temperature and be in equilibrium throughout that range. If cooled below saturation point, salt will fall out of solution, but it will return into solution if the temperature be raised to the original point.

Iron saturated with phosphide at 1,050 deg. C. parts with a portion of it when the temperature falls and sufficient time is allowed to admit of its segregation, and, like the salt solution, it takes it up again when the temperature is raised.

Iron containing less phosphorus in solid solution, saturated at a lower temperature, also parts with its phosphorus when the temperature falls.

So far as the experiments go, free phosphide did not form from solid solutions containing less than 0·6 per cent. phosphorus, but it seems more than probable that if the heating at lower temperatures than 700 deg. C. had been prolonged for months or years instead of for hours, crystallisation would eventually have occurred. It is obvious that as the metal becomes colder its particles become more rigid, and segregation into crystals must be correspondingly slower.

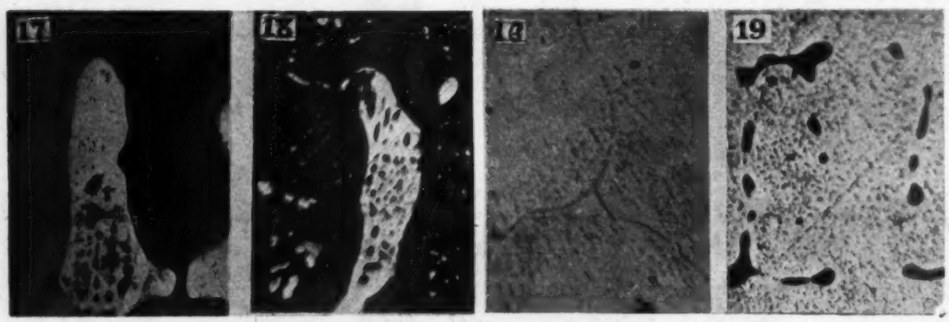
As the crystals of rhabdite in the Mexican meteorite, embedded in a matrix containing very little phosphide in solid solution, dissolve at 600 deg. C., and possibly at lower temperatures, it is obvious that they must have originally fallen out of solution at relatively low temperatures, probably below 600 deg. C., and then, only after a very extended period of heating.

A crystal of common salt, when placed in a large excess of water, begins to pass into solution at the surfaces, and, if there were no free liquid motion of the solution, the portions immediately surrounding the crystal would become saturated. If the temperature were then lowered, some of the salt would at once pass back from the saturated layers and recrystallise on the solid crystal.

An impossible condition of rigidity and immobility has been assumed so as to bring it into line with what occurs when a solid dissolves in a solid. It has been shown that on heating iron containing crystals of iron phosphide the phosphide at first forms strong solutions in iron round about them, and that on lowering the temperature some of the phosphide recrystallises on to the outside of the remaining portions of the original crystals.

If a crystal of common salt is suspended in water in nearly saturated solution, and the latter is allowed to evaporate spontaneously until the liquid becomes near the point of saturation, the free crystal will exert attraction and draw to itself the first portion of the salt that tends to fall out of solution before any is deposited elsewhere. This peculiarity is constantly met with in the alloys under consideration.

The large and relatively thick envelopes of phosphide surrounding the columns of Series I and V* suggest that they were formed in advance before the genesis of idiomorphic crystals in the centre of the columnar crystals of iron, and that their attraction for phosphide of iron was exerted for a considerable distance, a distance corresponding to the width of the borders which surround the layers of Fe_3P, borders which eventually became impoverished of phosphide of iron, and then contained less phosphorus than the metal in the centre of the columns which were outside the attractive influence of the massive envelopes. When the temperature fell to the point favourable to the crystallisation of the phosphide in the body of the crystals the excess would fall out of solution and appear as idiomorphic crystals of phosphide of iron. As the conditions in the hearth of the blast furnace were not favourable for the phosphide of iron to fall out of the borders, which are weaker solutions, no crystals appeared in them. The same thing appears to have occurred in the Mexican meteorite referred to in Series II. The rhabdite crystals were fairly evenly distributed, but at intervals there were a few very large crystals, each surrounded by thick borders of metal practically free from any free phosphides. The actual width of these external borders measured about 0·600 mm., but varied with the size of the crystals.



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The solid solutions of phosphide of iron in iron are in some respects similar to solid solutions of carbide of iron in the solvent eutectoid (the hardenite of Arnold), containing 0·9 per cent. carbon. The solutions in each become fully saturated at about the same temperature, 1,100 deg. C. After saturation, as the temperature falls, crystals of carbide or phosphide, as the case may be, fall out of solid solution, and equilibrium is established within a range at every temperature. They re-dissolve again as the temperature rises. The last trace of carbide, dissolved in the eutectoid, crystallises out at a point just above the critical point Ar 1–2–3. On cooling below this, the solvent itself breaks up into ferrite and carbide, producing pearlite. In the case of the phosphide solid solutions, the solvent is iron, and there is reason to believe that at some temperature, if almost infinite time were given, all the phosphide would also crystallise out. The exceedingly minute quantity of phosphide remaining in solid solution in the Mexican meteorite may be taken as tentative evidence that such would be the case. There can be little doubt that this interesting alloy took an exceedingly long time to cool down through the range of temperature favourable for the crystallising of the phosphide.

No reference has been made to the allotropic condition of the respective solvents of carbide and phosphide of iron.

We know that the iron in the alloys saturated with Fe_3C above Ac 1–2–3 is in the gamma state. On the other hand, Professor Arnold and others have shown that the alloys of iron and phosphide rich in phosphorus do not give any arrest corresponding to Ac3, and the author has found that such solid solutions, in a coarsely crystalline condition, are not refined in structure on heating even at 1,200 deg. C., facts which lead one to conclude that the iron in such alloys never passes to the gamma state. When, however, carbon is caused to diffuse into the more dilute solid solutions, the structure is broken up. We may conclude, therefore, that when that occurs the iron changes to the gamma state.

* See paper on "Blast-furnace Bears" in a future issue.

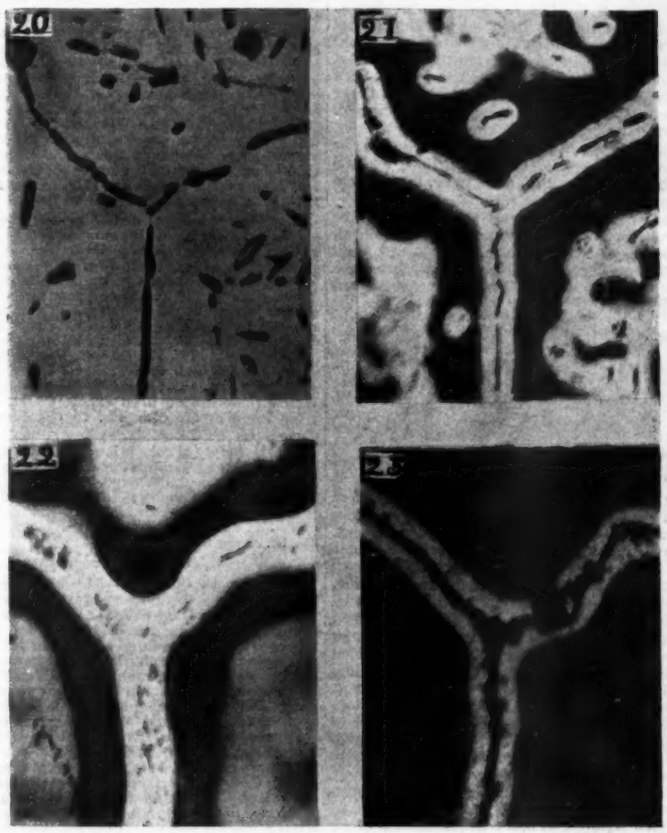
Much more research, however, is required in this direction before one can say we know.

APPENDIX.

METHODS FOR THE DETECTION OF PHOSPHORUS IN SOLID SOLUTION.

Solutions of phosphides in steel are attacked by very dilute acid reagents inversely in proportion to the phosphorus present. If a reagent contains a little copper in solution the parts of metal freest from phosphorus are most readily attacked and stained or coloured by a thin deposit of copper. The depth of the coloration in a given period gives a relative idea of the proportion of the phosphide present, but where the iron and phosphide approach saturation, no copper is deposited after a prolonged attack even with a strong reagent.

Three different cupric reagents have been described, one by Dr. W. Rosenhain, another by Mr. J. H. Whiteley, and a third by the author in the first part of this paper, published in 1915.



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Although the author's reagent has always given excellent results in his laboratory many experimenters have not been so successful. Professor H. Le Chatelier pointed out that the reagent might be improved by increasing the quantity of water, and this has been found to be the case.

It has, however, been found desirable to have two solutions, one stronger than the other, for whilst the dilute solution is suitable for etching steels containing a small quantity of phosphorus, it is not so useful when the phosphorus is much increased. The solutions used in this research contained :—

	a. Grammes.	*b.* Grammes.
Cupric chloride	1	5
Magnesium chloride	4	4
Hydrochloric acid	1 c.c.	1 c.c.
Water	20 c.c.	20 c.c.
Absolute alcohol	100 c.c.	100 c.c.

The attack by the cupric reagent not only stains primarily the parts freer from phosphorus, but bites into the metal, roughening the parts attacked, leaving the phosphoretic parts more or less unaffected and therefore smooth and bright. For this reason the objects when viewed under oblique illumination contain parts which appear dark, and parts quite light, the latter being the lower in phosphorus. As it is difficult to illuminate large surfaces by rays vertical to the surfaces, they should be examined under oblique and not direct illumination. As all the work done in this research was upon small specimens which required magnification, direct or vertical illumination was adopted.

In a paper the author read before the Royal Microscopical Society in 1905, reference was made to the fact that aqueous solutions of picric acid, after a short attack, stain solid solutions of phosphorus and iron a brown or black colour. Such a solution is made by dissolving 0·5 gramme picric acid in 100 cub. cm. of distilled water. It is invaluable in locating the parts in steel which are more or less saturated with phosphide.

Boiling solutions of alkaline picrates stain free phosphides a dark brown or black, but do not stain solid solutions of phosphide in iron, no matter how concentrated the solution may be. Free carbide of iron is similarly stained; for that reason the reagent does not enable one to distinguish one from the other. One way of doing this, when phosphides and carbides are together, is to heat the polished specimen to about 270 deg. C., when the phosphide will become blue by the time the carbide assumes a reddish brown coloration.

Professor H. Le Chatelier has suggested that electrolytic etching is generally under better control than attacking the specimens with acid reagents.

The photographs in this paper indicate how much can be shown by the application of modern etching methods. Indeed, but for them it would have been impossible to make the research.

DESCRIPTION OF PHOTOGRAPHS.

FIGS. 1 TO 6.

All the photographs represent steel containing 0·3 per cent. carbon and 0·3 per cent. phosphorus.

Nos. 1, 2 and 3 are of the same area.

Nos. 4, 5 and 6 are likewise of the same area.

All were magnified 50 diameters.

No. 1 was etched with nitric acid in alcohol.

No. 2. After repolishing No. 1, and etching with Stead's strong cupric reagent.

No. 3. After repolishing and etching with an aqueous solution of picric acid.

No. 4. Another section after heating to 960 deg. C. for 5 minutes and quenching in water, and etching with nitric acid in alcohol.

No. 5. After repolishing No. 4 and etching with Stead's strong cuprie reagent.

No. 6. After repolishing No. 5 and etching with aqueous picric acid solution.

FIGS. 7 TO 11.

All the photographs represent a homogeneous alloy of iron and phosphorus containing about 0·5 per cent. phosphorus, after carburising by cementation at 960 deg. C. in charcoal.

No. 7 is the cemented bar after polishing and etching with strong cupric reagent. × 2.

No. 8 was quenched in water directly it left the cementation vessel, and was etched with nitric acid in alcohol. The dark areas are martensite, the white parts ferrite. × 100.

No. 9. The same specimen as No. 7, after repolishing and etching with weak cupric solution. × 100.

No. 10. A carburised piece of the cemented bar corresponding to No. 8 after slow cooling from 960 deg. C. and etching with nitric acid in alcohol. × 100.

No. 10A represents the most carburised part of the cemented bar, etched with acid, after quenching from 1,250 deg. C.

No. 11 represents a part of the quenched bar farthest away from the charcoal, where carburisation had just commenced, after etching with nitric acid in alcohol and then by a weak cupric reagent. × 330.

FIGS. 12 TO 19.

No. 12. An alloy containing about 2 per cent. phosphorus, heated and cooled down with 3 tons of molten blast-furnace slag, after etching with nitric acid. The white parts are free phosphide of iron which had crystallised out of solid solution on slow cooling. × 60.

No. 13. A part of the same alloy as No. 12 after reheating at 1,000 deg. C., showing the phosphide passing back into solid solution. × 60. This experiment was made in 1889.

No. 14. A section through three columnar crystals of decarburised iron, found in the hearth of one of Messrs. Bolckow, Vaughan and Co.'s blast furnaces, showing thick envelopes of free iron phosphide and minute crystals of the same substance in the body of the metal, after etching with strong cupric reagent. × 50.

No. 15. The same as No. 14, after heating to 900 deg. C. for 5 minutes to cause most of the phosphide to pass into solid solution, and afterwards to 780 deg. C. for 6 hours to allow it to recrystallise out of solid solution. × 330.

No. 16. A portion of the same specimen after heating at 1,000 deg. to 1,050 deg. C. for 6 hours, to cause all the phosphide to pass into solid solution and produce perfect homogeneity, after which it was reheated for 6 hours at 800 deg. C., to allow the phosphide to crystallise out again. It was etched by boiling in strong picrate of soda which stained the phosphide black. × 330.

No. 17. An alloy containing 2·2 per cent. phosphorus, after heating to 1,050 deg. C. to produce a saturated solid solution of phosphide in iron, after which treatment—excepting in the binary eutectic areas—there were no free phosphide crystallites. It was then reheated for 6 hours at 980 deg. to 1,000 deg. C. and was examined, after etching with picric acid in water. The minute clusters of white specks are crystallites of free phosphide.

No. 18. A portion of the same metal as No. 17, × 330, after reheating for 6 hours at 820 deg. C., showing that the minute crystallites in No. 17 have grown considerably.

No. 19. An alloy containing 2 per cent. phosphorus, after long heating at 1,000 deg. to 1,050 deg. C., and afterwards for 6 hours at 820 deg. C. It was etched by boiling picrate of soda. The large black parts are the remains of the eutectic, the smaller dark parts are crystallites of phosphide which formed on heating at 820 deg. C. × 330.

FIGS. 20 TO 23.

These photographs illustrate the gradual passage of the phosphide into solid solution by heating for increasing periods at 960 deg. C. the same section of three juxtaposed decarburised columnar iron crystals from a Cleveland furnace bear. No. 23 shows that by reheating No. 22 at 800 deg. C. for 1 hour a portion of the phosphide recrystallises out again from the parts richest in phosphorus.

No. 20 is the original section. × 330.

No. 21 is the same as No. 20 after heating at 960 deg. C. for 5 minutes. × 330.

No. 22. The same as No. 21 after further heating to 960 deg. C. for 15 minutes. × 330.

No. 23. The same as No. 22 after further heating at 800 deg. C. for 1 hour. × 330.

It is impossible to study the evidence without wondering and trying to connect the known with the unknown. It is, however, important to try, even although what is advanced may require modification.

The research in this absorbing field has just begun, and it is believed that others will endeavour by experiment and observation to shed more light on many points which remain obscure.

As usual, I am under obligations to many friends for assistance in this research: Mr. F. M. Percy, of Wigan; Mr. George Ritchie and his chemist Mr. D. Sillars; Mr. F. Outhwaite and his furnace manager and foreman smith; also my assistants, Messrs. Jackson, Scholes, Bellwood and Towers.

By kind permission of some of the gentlemen concerned I have pleasure in stating that rough cut specimens, from blast-furnace bears and other material used in this research, suitable for microscopic work, will be supplied free of cost, if application is made to me at my address, care of Pattinson and Stead, 11, Queen's-terrace, Middlesbrough.

LONDON ASSOCIATION OF FOREMEN ENGINEERS.—The sixty-fifth anniversary festival of the London Association of Foremen Engineers took place at Cannon-street Hotel, London, on Saturday, the 11th inst. The attendance of members and visitors was so large that the big dining hall could not accommodate them, and an overflow hall had to be utilised for the purpose. The gathering was presided over by Sir Hugh Bell, D.C.L., LL.D., the vice-chairman being Mr. Anthony A. A. Byrd, president of the association. The association represents a body of men whose invaluable work under most novel and difficult circumstances during the war places the whole nation under a debt of gratitude to them.

PRECISION SCREW-CUTTING LATHE.

FOR various reasons into which we need not enter here, great difficulty was at first experienced in meeting the demands of the Ministry of Munitions for accurate screw gauges. Indeed, at one stage of the work the number of rejections was so large that some highly competent engineers were inclined to the belief that the degree of precision demanded was commercially unpracticable, and some pressure was exerted to obtain a reduction of the standard of excellence demanded. This advice, however, was declined by the authorities, who adopted the alternative course of giving inducements to the further development in this country of machine tools suitable for securing the precision desired.

We now illustrate, on page 580, a lathe which, under the circumstances above referred to, was designed and made at the request of the Ministry by Messrs. Bryant Symons and Co., of 320, St. John-street, London, E.C. This lathe, notwithstanding the high quality of the work it is capable of producing, is not a scientific instrument, but a machine tool intended for the making of commercial products. It embodies some unusual features. In the first place, both centres are dead centres, thus ensuring that work meant to be round really is round and not perhaps a little elliptical; and in the second place the lead screw can have its effective pitch varied at will, so that it can produce a screw which is of slightly greater or slightly smaller pitch than the standard. In this way any shrinkage which may occur on hardening a gauge can be provided for in advance as well as errors due to temperature changes. Further, the lead screws of these lathes are all separately tested and a correction bar is fitted to compensate for the local errors in each lead screw. Each tool, moreover, when sold, is accompanied by a certificate from the National Physical Laboratory as to its performance. This certificate gives the errors found in a screw 8 in. long actually cut on the machine, and thus testifies that the lathe is in satisfactory condition for cutting screw gauges.

A general view of the machine fully equipped is represented in Fig. 1; whilst Fig. 3 shows it mounted on a cabinet pedestal fitted with a roll top cover which excludes dust and dirt when the tool is not in use. All the principal components of the tool, the castings as well as the lead screws and gears are thoroughly aged after rough cutting, and again after the first finish cut before being finally finished. Internal strains are thus fully relieved, and the consequent changes of form which might otherwise impair the accuracy of the tool are guarded against.

The bed of the machine, which is of close grained iron, is illustrated in Fig. 2. It is supported on the three point principle. The ways for the head stocks are distinct from those on which the tool saddle runs. For the headstocks one of the ways has a flat face and the other an inverted V-section. The saddle ways are mounted on brackets cast on one side of the bed as shown, the weight being carried by flat surfaces with which the guiding surfaces make an angle of 60 deg.

The lead screw is, as will be seen, arranged immediately below the saddle slide, so that the drive to the latter is taken centrally, and at the same time the screw is well protected against damage or dirt. A hard Bessemer steel has been adopted as the material for the lead screw, with a view to securing a high resistance against wear. The screw is cut in a succession of operations between which ageing periods are allowed. It is of relatively large diameter and is normally given 16 threads per inch, though a metric pitch is supplied if desired. The thread form is represented in Fig. 4 annexed the angle between the threads being 30 deg.

There is, it will be seen, a considerable clearance over the crests of the threads and in the case of the nut these clearance spaces have parallel sides as indicated. As the nut is made in halves this arrangement permits of it being thoroughly bedded, and it can, moreover, be readjusted in case of wear. This nut is of phosphor bronze, two diameters long. The two halves are permanently bolted together so as to make practically a solid nut. It is thus never disengaged from the thread. It is mounted so as to be free from end play, but it can be rotated through a small angle in either direction. It is in this way that the necessary corrections are provided for.

As indicated in Fig. 2 a finger extends from the nut to a guide slot or correction bar, which rests on machined brackets cast on the lathe bed as shown. The form of this slot is based on the National Physical Laboratory measurements of the screw errors, these being compensated for by a slight rotation of the nut relatively to the lead screw. The correction bar is, moreover, pivoted on its support and can be swung over a little in one direction or the other. Such a swing has the effect of either increasing or diminishing the effective lead of the screw.

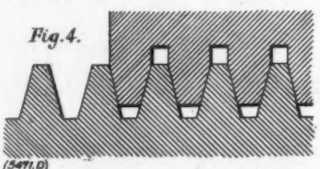
In making a gauge which is to be hardened the process is to turn a blank from the metal to be used. This is then hardened, and the consequent shrinkage measured. The correction plate is then swung round so as to increase the effective lead of the screw by the amount required to compensate for the shrinkage observed. A graduated index plate is supplied which indicates directly the amount of swing necessary to change the effective pitch by one ten-thousandth of an inch per inch of screw length, either plus or minus. The total adjustment available on a standard machine is from + 0·001 in. to — 0·001 in.

As already stated the nut on the lead screw is permanently closed, so that the direction of motion of the saddle has to be reversed by reversing the lathe. This reversal is effected by the use of the crossed belt system, and advantage is taken of this to provide an automatic throw-out at each end of the saddle travel. For this purpose a stop bar connected at one end to the reverse lever and at the other sliding in a bush, is provided in front of the bed as best seen in Fig. 1. Adjustable stops on this bar throw the driving clutches out of gear when the saddle comes in contact with them.

The fixed heads, as already mentioned, are provided with dead centres on which the work is rotated by a catch plate which rides on the spindle which holds one of the dead centres, and is driven by gearing as indicated. The forward and reverse pulleys are grooved for belts, and are engaged by claw clutches as shown. Four forward and two reverse speeds are provided for, the speed for the latter being high so as to reduce the time lost in running back the saddle.

Special care is taken in securing the accuracy of the change wheels, and the keyways are a push fit on all spindles and sleeves. An extension of the head stock to the front of the bed provides a long boss forming a bearing for the lead screw. Great attention is paid

Fig. 4.



(5471.0)

in finishing the ends of this boss to secure the perfect surfacing of the lead screw abutments so as to minimise the introduction of periodic errors in threads cut. A cast-iron guard, shown in Fig. 3, covers the change wheels and banjo frame when the tool is in use.

The tailstock of the lathe is mounted on a cross-slide, which enables it to be set over for taper work. Dead alignment for parallel turning is secured by a hardened pin fitting into holes reamered in the tailstock bottom plate and cross slide. Fine setting lines are provided to show when these holes are co-axial, thus avoiding the possibility of damaging the holes by an attempt to enter the pin with the tailstock out of position. The spindle is hollow and a screwed ejecting rod is provided for pushing out the centre when required.

The saddle is adjustable on its carriage, both axially and transversely. The axial adjustment is of short range, and the bearing is long, so that great stiffness is secured. The screw for this adjustment has a head divided to give readings to one four-thousandth of an inch. The nut is split and fitted with clamping screws to eliminate back lash.

The transverse slide on the saddle has no actuating screw, but is moved in or out by the hand lever shown in Fig. 1. A micrometer stop is, however, provided as indicated, the head reading to 0·00001 in. Both this head and that for the axial traverse can be unclamped so as to "set to zero" whatever the position of the tool holder. The latter is provided with a surface accurately machined to the level of the lathe centres, so that the height of the cutting tool can be accurately adjusted whatever the position of the carriage. A magnifier is mounted on the saddle as indicated and can be used more conveniently in tool setting than a glass fixed to the operator's eye.

The particular lathe illustrated on page 580 is intended for cutting screws up to 2 in. diameter and up to 8 in. long, and with any pitch from the finest up to eight threads per inch; but the makers also construct machines of similar design capable of dealing with greater lengths of work. We may add that in the production of these lathes the highest excellence of workmanship has been aimed at throughout.

LUBRICATING OILS.—The Ministry of Munitions has called a general meeting of the representatives of the lubricating oil trade to be held in London on Thursday, the 30th inst., for the purpose of discussing the position of supplies of lubricating oils, and of considering any suggestions which may be put forward on behalf of the trade. Those who desire to attend, but have not received a letter from the Ministry on the subject, should apply to the Controller, Mineral Oil Production Department, Ministry of Munitions, 8, Northumberland-avenue, W.C. 2.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—With the current month's home allocations for Cleveland foundry iron placed, and the usual check to business at Whitsuntide, the market is quiet. At the same time there is no relaxation in the pressure for delivery. Iron is plentiful, and as supply of trucks is steadily improving, and increasing use is being made of water-borne transport wherever possible, distribution is larger. Forge iron continues in good home demand, and as this quality does not come under the allocation system sales are being put through on both early and forward account. Consumers are keen to place orders ahead, but makers still hesitate to commit themselves forward to any great extent. Foreign trade is quiet, and exports, except to France, are small. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are 114*s.* and No. 1 is 119*s.*

Hematite Iron.—Production of East Coast hematite iron is well maintained and with but small quantities being exported, home requirements are quite adequately covered. Further increase of output, however, is not probable, and thus existing licences for export are likely to be met only at the expense of home trade, when steamers are available. The use of basic iron and scrap for steel-making has assumed very large proportions, and promises to continue to increase, so that more relief to the hematite position may be looked for. Nos. 1, 2 and 3 East Coast brands are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for export to France and Italy.

Manufactured Iron and Steel.—Output of manufactured iron and steel is enormous. The huge demand for shipbuilding material tends to increase, but there is good ground for belief that all requirements will continue to be satisfactorily dealt with. Many works were closed Monday and Tuesday, but one very large establishment worked through the holidays. To home customers common iron bars are 13*l.* 17*s.* 6*d.*; best bars, 14*l.* 5*s.*; double best bars 14*l.* 12*s.* 6*d.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel hoops, 17*l.* 10*s.*; and heavy steel rails, 10*l.* 17*s.* 6*d.* Whilst there are no fixed export prices, they may be given approximately at 40*s.* to 60*s.* above the home quotations.

Coke.—Supply of coke is hardly adequate to the heavy demand for home and for export. Shipment to neutrals is only quiet, and the export quotation thereto, both for furnace and foundry description, is firm at 50*s.* For home use foundry coke is 38*s.*; average blast-furnace kind, 33*s.* at the ovens, and quality low in phosphorus 35*s.* 6*d.* at the ovens.

THE STINNES CONCERN.—The large German undertakings continue their process of extension and expansion. Thus the firm of Hugo Stinnes, Mülheim, which for years has kept increasing its hold upon the German coal business, and done a large business in English coal and also owned branch establishments and mines in England, has now taken over a number of concerns in Hamburg, Berlin and elsewhere. In the former place the shipping concern of H. W. Heilmann and the Elbe briquette works; the Holm and Molzen English coal-importing concern, Flensburg; the Königsberg briquette works, Königsberg; the Westphal briquette works, Harburg; the Hansa coal and coke works, Bremerhafen; and the Berlin Coal Supply Company, are likewise under the control of Hugo Stinnes, who has, through extensive purchases of property, secured a preponderant position. Hugo Stinnes is also extending his interest and influence in shipping, thus in the Woermann Line, the Hamburg-American Line, the Midgard yard, Nordenham, and the Nordsee yard, in Emden.

REPAIRING DAMAGED SHIPS.—A highly important work in maintaining the number of ships afloat is that done in the repair yards. These have been co-ordinated throughout the country and all possible accommodation has been brought into use, with the result that an immense amount of work is now being turned out. In the period from August 3, 1917, when the directorate got its organisation to work, to April 25, 1918, these yards have repaired and restored to service 5,307 vessels, representing an aggregate gross tonnage of 16,150,000 tons. This gives a weekly average for the period of 414,105 gross tons, but the weekly average for some weeks past has risen to over 500,000 gross tons, and is steadily increasing. As much as 2,120,301 gross tons of shipping have been in hand during one week, of which, during the week, more than 500,000 tons were restored to service. The amount restored in one week has reached the figure of 598,000 gross tons. Five ships, each over 20,000 tons, have left the yards ready for service in a single week. Although our accommodation for big ship repairs is the best in the world, it is none too plentiful, and the greatest economy is observed in its use. Not a stroke of work is done on a vessel in dock that can be done afloat. The moment a damaged ship has completed all under-water repairs, she is taken out of dock, and all other repairs are completed afloat. In the case of a very badly damaged hull, which will take a considerable time to restore to floating condition, the other repairs proceed simultaneously so that when the ship can float she is completely ready for service. In all cases labour and material are economised to the fullest extent possible. Only work of an imperative necessity to fit the vessel for sea service is carried out, thus all waste is avoided. The time of a vessel's being off service is limited in every case as far as possible.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The manufacture of munitions of war, and the material required by the shipbuilding yards for the construction of standard vessels and other craft destined to play a part of more or less importance in the present struggle for supremacy, continues to occupy the attention of steelmakers in the West of Scotland, and every mill which will run is being utilised. Pressure for delivery is still as heavy as ever, and in some establishments considerable difficulty is experienced in turning out the material to time, and this even with increased facilities for output. Without doubt the present rate of output is colossal, and while at the moment the shipbuilders seem to be satisfied with their supplies—in certain other quarters the reverse is the case. It is fully expected that ere long more material, in the shape of steel ship and boiler plates, sections, &c., will be required for the shipyards, but in the meantime the fact that the requirements are being so well met has freed some further consignments for Government purposes in France and India. Other than this very little export is being put through.

Malleable Iron Trade.—In the malleable iron industry work of national importance has first place, and the mills are running to their fullest capacity in the production of sectional material and small rounds required for the purposes of the war. The output of both the iron and the steel departments is being disposed of in this manner, and a decided falling-off in the re-rolling of shell discard steel has taken place, although whether this will continue or not is another matter. Report asserts that changes in the price of steel may be expected shortly.

Scotch Pig-Iron Trade.—Conditions of great activity rule in the pig-iron trade, hematite being in heavy demand for the steel works and forge and foundry iron for the iron works and the engineering shops. With every ton produced going direct into use, no stock can be accumulated. To the best of their ability, makers endeavour to distribute the output in strict accordance with the necessitous requirements of each consumer. Export has tapered away to vanishing point.

Shipbuilding at Bo'ness.—In furtherance of the scheme for the development of the Forth area, an inquiry regarding ground for the construction of a shipbuilding yard in the neighbourhood of Bo'ness has just been submitted to the Bo'ness Town Council. The idea of the company making the inquiry is to acquire ground and lay down plant suitable for the building of a modern class of vessel. Naturally the proposal has been very well received, Provost Grant asserting at the meeting at which the letter was read that, on the foreshore of Bo'ness, there was plenty of good ground for the desired purpose, besides giving voice to the opinion that everything possible would be done, alike by the Council, the landed proprietors in the district and the citizens generally to further the interests of a new industry in the neighbourhood. A favourable report of the prospects of the proposed scheme is being despatched to the inquirers, and the community awaits with expectancy the result of the overtures.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Sheffield Supplies of Refractory Material.—In an interesting paper to the Refractory Material Section of the Ceramic Society last week, Professor Fearnsides pointed out that in its possession of ample reserves of those kinds of mineral raw material which were required for the construction and maintenance of all kinds of high temperature furnaces for the making and working of iron and steel, the Sheffield district was particularly fortunate, especially in the local development of the beds of refractory mineral material which formed an important fraction of the lower part (the Halifax Group) of the Lower Coal Measure Series. Towards the top of the Halifax group of measures occurred the famous Sheffield ganister, which provided the staple raw material on which the local silica brick-making industry had been built up. So important were the products of this minor industry to the major metallurgical industries that the mining of ganister measures associated with the Halifax hard bed of coal might fairly claim to rank as a national key industry, essential to the existence, and certainly to the prosperity of the Sheffield trades, and it was clear that without a supply of such ganister, modern methods of steel-making as practised in Sheffield could not be continued.

Iron and Steel.—The abandonment of the Easter holidays and the strenuous work of the past two months has placed our munitions industries again in a position of security, and with few exceptions local works set down for an extended holiday this Whitsuntide. The second quarter of the year has so far been one of hard work in every department. The March offensive marked renewed activity in the steel trade, which for some time had been a declining quantity. The increased call for munitions, and the pressure in the aeroplane, tank, motor and shipbuilding industries called for vigorous efforts on the part of local makers, and it has been necessary to commandeer an increasing amount of female labour to take the place of the young men who have been released for the army. Orders for saws, twist drills, files and other tools for army, Admiralty and general purposes are coming to hand in ever-increasing quantities, and work will be renewed with full order books.

South Yorkshire Coal Trade.—The shortage of supplies on the Sheffield coal market has been further accentuated this week by the holidays. Business in house fuel is very restricted. Collieries, after supplying the weekly requirements of the London area, have very little available for distribution elsewhere. Local stocks are short, and merchants badly in arrear. Practically the whole of the output of manufacturing fuel is absorbed on requisition account, and collieries are pressed all round for supplies. Prices are at the full maximum rates. There is considerable inquiry for tonnage for export to neutral countries, but no supplies are available. Slacks are scarce, contracts in arrear, and practically no coal on the open market. Blast-furnace coke is in brisk request. Quotations show no change.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—In view of the holidays more especially there has been little doing in the local markets this week, and comparatively few colliery salesmen put in an appearance on 'Change yesterday morning and to-day. The position is unchanged, except in so far that the shortage of coal is becoming more acute and this is accentuated by the interruption caused by the Whitsun holidays. Practically all that is produced for export is absorbed to meet the most essential requirements. For private account merchants are finding it more difficult than ever to obtain the release of coal due under contracts and for the moment one cannot see any immediate prospect of improvement. Then, again, the stoppage of the Tredegar Collieries involves an appreciable restriction in the supply of Monmouthshire coals, and an effort is being made to induce other collieries to indulge in a sympathetic strike. How far this will succeed remains to be seen, but the position at present gives cause to a good deal of concern as the extreme section in the coalfield are always on the alert to capitalise the least symptom of unrest.

Newport.—The shortage in the supply of coal continues unabated and the exceptional paucity of washed smalls is reacting seriously on the production of foundry coke and, in a lesser degree, on the manufacture of furnace coke. The South Wales Coal and Coke Supplies Committee has been asked to take steps with a view to the mitigation of the effects of the loss of washed smalls due to the stoppage of work at the Tredegar pits, but as the supply of these coals has been relatively scarce for some weeks past, it is difficult to see how the supplies for foundry coke purposes can be appreciably increased from other sources.

Irregular Colliery Stoppages.—It was only at the end of last March that the Joint Coal Board, at the suggestion of the workmen's representatives, agreed to the establishment of a Joint Standing Disputes Committee, which meets weekly in order to deal expeditiously with any trouble that may arise at individual collieries, and thus prevent stoppages. It was on the understanding that disputes would be immediately referred to this committee that the owners agree to withdraw notices issued against a large number of workmen for illegal abstention from work. Unfortunately, however, even the new machinery set up has not had the effect of eliminating these disconcerting and embarrassing dislocations of trade, and the most notable of these is the sudden stoppage of the Tredegar Collieries, in the Monmouthshire Valleys, where upwards of 6,000 men are employed. The present *impasse*, as pointed out by Mr. A. S. Tallis, the general manager, is really caused by the refusal of the local leaders of the men to refer the points at issue to the disputes committee of the Joint Board. Instead of adopting this course Mr. Tallis was asked to meet a committee formed by the extreme section of the workmen and known as the "Combine Workmen's Committee"—a body which comprises representatives of workmen of other collieries as well as those at which the disputes arose. This committee the colliery management have never before met and have no power to meet without setting up a new precedent to those laid down in the agreement of March last. For the moment there is no sign of a settlement being attempted; on the contrary, delegates are being sent from the colliery to other districts with the view of endeavouring to bring about other stoppages.

The Miners Holidays and Shortage of Coal.—All the collieries in the Welsh coalfield were idle on Monday and Tuesday, but the men's leaders promised that there should be a general resumption of work to-day. It is estimated, however, that not more than half of the men returned to work to-day. Doubtless this is accounted for mainly by the extraordinarily fine weather, but these wholesale abstentions seriously jeopardise the supply of coal both for shipment and for home consumption. The District Coal and Coke Supplies Committee are taking steps to relieve the position as far as possible in the case of exports, and from a circular issued to colliery companies to-day, it is shown that in order to facilitate shipment, supplies of coal for home consumption are to be reduced wherever possible. Information is being compiled as to works to which supplies can be cut down, and in the case of household coals, colliery companies supplying these qualities are advised that they should no longer send truck loads of coal to individual private consumers, and deliveries to individual factors and merchants should be reduced by 10 per cent. in June, as compared with the quantities supplied in the same months in 1915.

THE CONCRETE UTILITIES BUREAU.—A permanent collection of concrete products has been arranged at 143, Grosvenor-road, near Vauxhall Bridge. This collection is interesting in view of the fact that at the present time economy in the use of timber and steel is of paramount importance. The exhibit has been provided by the above bureau, whose address is 6, Lloyd's Avenue, E.C. 3.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS; MIDLAND SECTION.—Friday, May 24, 7.45 p.m., at the Imperial Hotel, Birmingham, Mr. Langley will read a paper on "The Early History of the Steam Engine."

THE SURVEYORS' INSTITUTION.—Monday, May 27, at 5 p.m. The annual general meeting of the Institution, to receive the Report of the Council and announce the result of the Election of Officers for the ensuing year. The prizes awarded to successful candidates in connection with the recent Parliamentary and Professional Examinations will be presented by the President at this meeting.

THE JUNIOR INSTITUTION OF ENGINEERS (NORTH-EASTERN SECTION).—Tuesday, May 28, at 7.15 p.m., at the Mining Institute, Neville-street, Newcastle-on-Tyne, a paper will be read on "Lightning Phenomena," by Mr. S. A. Stigant.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, May 28, at 8 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. The following paper will be read: "The Application of Electrical Power to Oilfield Requirements," by Mr. J. Wilfred Burford, M.I.Min.E., A.M.I.E.E.

THE ROYAL SOCIETY OF ARTS.—Wednesday, May 29, at 4.30 p.m. A paper on "Organic Chemistry in Relation to Industry" will be read by Mr. Martin O. Forster, D.Sc., Ph.D., F.R.S. The chair will be taken by Sir William A. Tilden, D.Sc., LL.D., F.R.S.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 31, at 5.30 p.m., a discourse will be delivered by Mr. Lawrence Binyon. The subject will be "Poetry and Modern Life." Afternoon Lectures at 3 p.m.:—On Tuesday, May 28: Sir Arthur Newbolt, D.Litt., on "The Poetry of Thomas Hardy: The Dynasts" (Lecture I). On Thursday, May 30: Lieutenant-Colonel Sir Francis Younghusband, K.C.S.I., K.C.I.E., on "The Abode of Snow: Its Appearance, Inhabitants and History" (Lecture II). On Saturday, June 1: Professor Charles J. Patten, M.D., Sc.D., on "Problems in Bird Migration" (Lecture II). General meeting, Monday, June 3.

LOSSES OF MERCHANT TONNAGE.—The Secretary of the Admiralty makes the following announcement: The losses of British, allied and neutral merchant tonnage due to enemy action and marine risk during the month of April, 1918, compared with preceding periods are set out below:—

Gross Tonnage.

Period.	British.	Allied and Neutral.	Total.
Second quarter, 1917	1,361,870	875,064	2,236,934
Third quarter, 1917	952,938	541,535	1,494,473
Fourth quarter, 1917	782,889	489,954	1,272,843
First quarter, 1918..	695,380	447,350	1,142,730
April, 1918	220,709	94,393	305,102

The tonnage of steamships of 500 gross tons and over entering and clearing United Kingdom ports from and to ports overseas was as under:—

Period.	Gross Tons.
January, 1918	6,336,663
February, 1918	6,326,985
March, 1918	7,295,620
April, 1918	7,040,309

This statement embraces all United Kingdom seaborne traffic other than coastwise and cross-Channel.

ELECTRIC FURNACES FOR STEEL CASTINGS.—The Michigan Steel Castings Company, of Detroit, has, since winter, 1915–16, been using two electric furnaces of the Héroult type for making small castings for automobile trucks, &c.; the average weight of a casting is 20 lb., but the weight may only be ¼ lb. or rise to 200 lb. and even 2,000 lb. Before adopting electric furnaces, which the president of the company, Mr. R. F. Flintermann, thoroughly recommended to the meeting of the American Electrochemical Society, held at Detroit last year, they had used crucibles. The crucibles were expensive, lacked uniformity, and contaminated the steel with carbon. The side-blown Tropenas converters, then tried, were cheaper and more satisfactory, as larger bulk and high manganese percentages could be dealt with. The electric furnaces, one of 6 tons, the other of 3 tons, gave a superior steel, however, the superiority being attributed to the low content in sulphur and in oxides and slags. The furnaces were originally lined with magnesia. The rising cost of magnesite, however, induced the company to pass to acid linings and the results have been encouraging, especially when working the "reverse-duplexing process." By this method part of the metal is melted and refined in a basic furnace which can be run at comparatively low temperature; sulphur and phosphorus are eliminated, even when the raw material (screw machine turnings) is rich in these elements and could not entirely be treated in acid furnaces. The charge is then added to another portion of the steel which has meanwhile been fused in an acid furnace, in which the deoxidation is completed. There is less trouble with the slag in acid furnaces, it was claimed. That statement and the advantages of acid and basic linings and of the reverse-duplexing formed the chief subjects for the discussion. Mr. Flintermann did not claim that electric-furnace steel is free from blowholes, as Girod and others have asserted. But he mentioned that long, thin-section castings such as cross-members on engine supports, had inclined to develop shrink cracks, when made in the converter, and that they had no trouble from that cause with the electric furnaces which had been running continuously since their installation.

HIGH-PRECISION SCREW-CUTTING LATHE.

CONSTRUCTED BY MESSRS. BRYANT SYMONS AND CO., ENGINEERS, LONDON.

(*For Description, see Page 578.*)

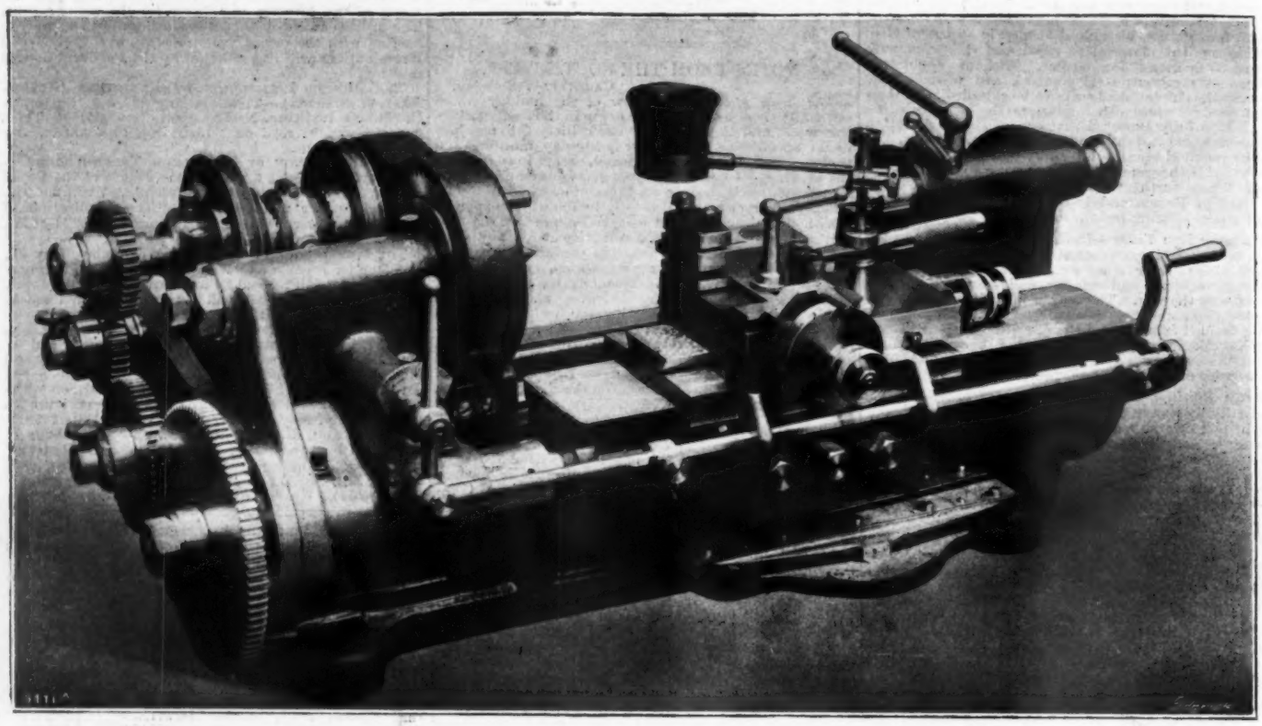


FIG. 1.

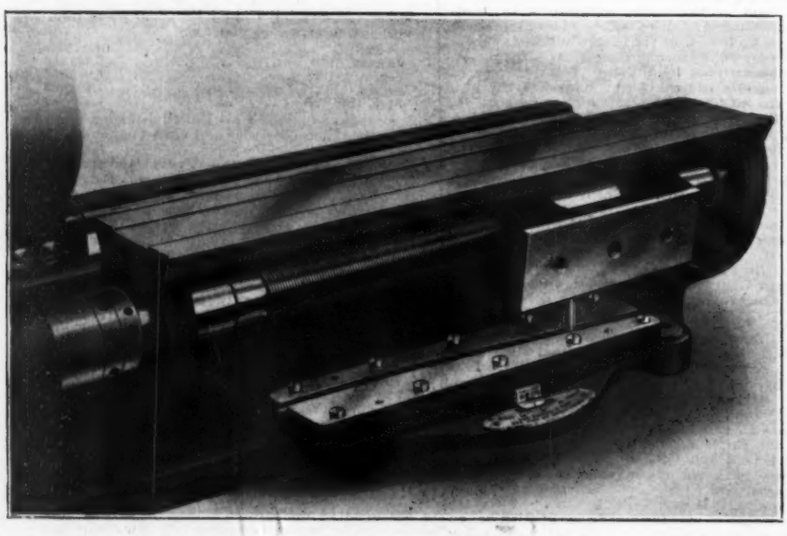


FIG. 2.

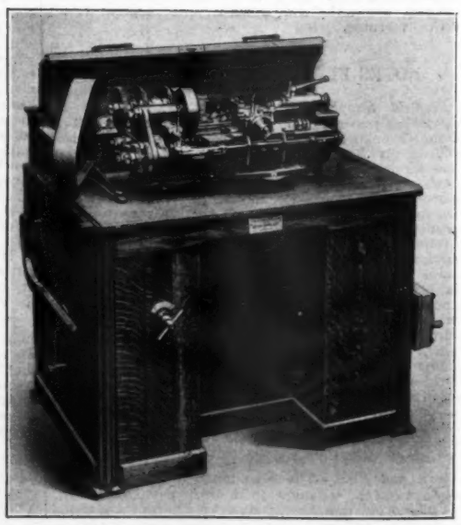


FIG. 3.

THE INSTITUTION OF GAS ENGINEERS.—The annual meeting of the Institution of Gas Engineers is to take place on June 4 and 5, at the Institution of Civil Engineers, Westminster, under the presidency of the Right Hon. Lord Moulton, G.B.E.

PROPOSED ENGINEERS' CLUB FOR THE MIDLANDS.—A representative meeting was held on Wednesday, the 15th inst., at the Chamber of Commerce, Birmingham, in connection with the project for forming an engineers club in the Midlands. In opening the proceedings, the chairman, Dr. C. C. Garrard, M.I.E.E., remarked that in the future a great responsibility would rest upon the engineers and upon all occupying leading positions in the engineering industry in connection with the work of reconstruction rendered necessary by the war. It was felt, however, that as a body engineers did not have the power corresponding to their abilities. This was no doubt due to their being scattered and split up into a large number of organisations which had very little contact with each other. It was felt that the first thing to do was for engineers and those associated with them technically to come together and know each other. Guided by these considerations it had been proposed to found an engineers' club in the Midlands. The idea underlying the organisation was that it should offer all the advantages of a first-class social club combined with facilities for meetings, lectures, &c. It was thus hoped that it would become the meeting-place of the various technical societies in the district. Such a common meeting-place for these societies had long been desired in Birmingham. The following resolution was moved by the chairman, seconded by Mr. James Carrington, M.I.M.E., and carried unanimously: "That a Midland Engineers' Club be founded in Birmingham and that those present constitute themselves into a provisional general committee for the production of a scheme for such, with power to add to their number." Dr. C. C. Garrard, General Electric Company, and Mr. J. Fearn, Birmingham Small Arms Company, Limited, were elected provisional chairman and honorary secretary respectively.

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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For Canada—	
Thin paper copies	£2 5 0
Thick " "	£2 9 6
For all other places abroad—	
Thin paper copies	£2 9 6
Thick " "	£2 14 0

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3603 and 3608 GERRARD.

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With Four One-Page Plates of the LARDERELLO NATURAL STEAM POWER PLANT.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 579.

ENGINEERING.

FRIDAY, MAY 24, 1918.

ELECTRIC SHIP PROPULSION.

CONSIDERABLE interest is being evinced at the present time in electric ship propulsion. The name is perhaps rather misleading, in that the electric plant is simply used as a flexible gearing between the power generator and the propeller. The hydraulic analogy can aptly be applied in this case to explain the function of the main electrical plant.

We have recently described the first ship of considerable size so fitted out in this country, the Wulsty Castle, and those who have followed the trend of marine practice will be quite familiar with recent experiments and decisions in this connection in the United States of America. Special circumstances warrant special measures, and the problems to be faced by American naval engineers are somewhat different from those with which we in this country are confronted. The flexibility of the electric system of transmission permits of an economy of fuel consumption over a wide range of powers, and so of speeds of ship, that cannot be approached by any other system. Without the electric system most undesirable complications are introduced into the main turbines, including the addition of separate suitably geared cruising turbines, which only come into operation when the power and the speed have been reduced to a designed figure and so give an economy at reduced power which is, however, below that obtained by the electric system, and even then does not afford the same flexibility as is achieved by the latter. It will be clear that this advantage of economy over a wide range of powers is of special advantage to a navy which must operate at a considerable distance from its bases, this being the conditions for which the American Navy must provide.

Another great advantage of the electric system for war purposes is the manner in which many of the important units can be accommodated in positions of great immunity from damage, especially from torpedo attack. This is a condition of maximum importance under present-day war conditions, since with the electric system cables take the place of shafting, piping, &c., and can be well and readily protected. For war vessels of large power, especially where cruising economy and radius of action are of prime importance, the electric system of propulsion has therefore exceedingly strong claims and much to commend it.

The foregoing remarks do not necessarily apply to the system as applied to the propulsion of ordinary cargo vessels. The standard machinery for cargo carriers has been the triple-expansion steam engine and the Scotch cylindrical boiler. It is somewhat strange in the light of the great and extending application of the water-tube boiler ashore that it has made such little headway afloat in the mercantile marine. It has no economy over the Scotch boiler to offer, yet in weight, in quick steam-raising properties, good circulation and price it can afford many advantages with practically equal economy of fuel per unit steam generated. The reason that the Scotch cylindrical boiler has held the field must be sought for in its well tried qualities of being able to deal well with the great variations in quality of coal and of firing to which normally it is subjected. It is not a delicate boiler, is well understood by those using it, and the large volume of water contained gives a margin of safety from burning out or damage. Its long continued use is simply a proof of the conservatism of marine engineers arising out of the necessary condition that reliability comes first, and it does not mean that the water-tube boiler, with coal handling and firing appliances, will not be applied to mercantile marine use and that at an early date.

One condition required to be satisfied in the past by marine engineers was that, if the worst conceivable mishap occurred a repair, even a patch-up repair, could be effected and the ship brought to port. The only exception was the losing of the propeller in a single-screw ship, without a spare one on board. This condition of easy repair is admirably met by the Scotch cylindrical boiler and the reciprocating steam engine. The turbine has not yet been generally accepted for the propulsion of the average single-screw merchantman, although after the war little doubt is entertained that the geared turbine installations will take a very strong place in marine construction.

In spite of the opposition at the commencement of the reapplication of mechanical gearing between the main engines and the propeller, the rate at which mechanical gearing has been accepted is remarkable, and, furthermore, double reduction gearing is assured of an extensive and fair trial in the immediate future, although it cannot be said yet to have been really proved in practice. The turbine and gearing may be considered as the probable standard marine machinery of the near future, first of all for the larger twin-screw vessels, and later for the single-screw average cargo carrier. This represents a very long step, although no one would be so bold as to state that the double mechanical gear represents finality in the solution of the problem of reconciling the turbine to the propeller.

To consider the claims of the electric system, it must be compared with the geared steam turbines expanding the steam in two or more turbines and utilising the same amount of superheat. The question relative to superheat and superheaters afloat is not so simple as in land practice where they represent new standard practice. However, the superheater is gaining favour for ships and the difficulties relative to the astern turbine and superheat are in no way incapable of solution. The electric system has the advantage that the astern turbine is eliminated and that the main generators are kept running continuously in the one direction, so that the question of superheat is not fraught with the same difficulties. Elimination of the astern turbine, except in so far as superheat is concerned, is not such an advantage as has been made out by advocates of the electric and other similar systems.

The electric system will therefore fall to be compared with the double reduction-geared turbine in respect of:—(*a*) First cost. (*b*) Economy of operation in regard to fuel costs. (*c*) *Personnel.* (*d*) Reliability under sea-going conditions and facility with which repairs can be effected. (*e*) Weight and space occupied.

In regard to first cost, little can at present be said as the system is new and a small saving in fuel would cover a relatively large difference in capital charges, although the electric system with its extra conversion of energy and the cost of copper for cables, &c., would seem to be intrinsically expensive.

As regards economy of operation at sea, qualities of coal which vary from port to port, and the suitability of the firing which is an uncertain factor, make comparison difficult. With the electric system, until such time as marine engineers have been trained to a higher degree of proficiency in electrical matters, questions of *personnel* are bound to militate against its employment, and whilst electrical machinery has reached a great degree of reliability, yet its application to marine purposes must be very carefully studied lest certain conditions should not be satisfied. Of course the ques-

tion of repairs is always in favour of the simplest of all systems, and this cannot be said to be the electric system.

There are now several double-reduction geared ships in operation and others are being completed, so that we may hope at an early date to have such data as will enable a comparison to be made between these two systems on the lines as suggested above.

THE MINISTRY OF MUNITIONS EXHIBITIONS OF WOMEN'S WORK.

THE series of exhibitions of women's work given last year at London, Leeds, Newcastle, Sheffield, Birmingham and Manchester was resumed on Wednesday by one at the Whitechapel Art Gallery, opened by Mr. F. G. Kellaway, M.P., Parliamentary Secretary to the Ministry. It will remain open daily till June 20, from noon till 9 p.m. on weekdays and from 1 p.m. to 6 p.m. on Sundays, and is to be followed by a series running through the rest of the year, and held for a fortnight each at Nottingham, Liverpool, Swansea, Wolverhampton, Darlington, Glasgow and Aberdeen.

As before, the exhibits consist in part of specimens of work, and in part of photographs of women engaged not only on the production of such work but also on operations that cannot be reproduced conveniently within the walls of an exhibition. The specimens include parts of engines for aircraft, "tanks" and motor transport, as well as of Diesel engines, locomotives and turbines, and accessories such as magnetos, sparking plugs and air pumps; details of guns and gun sights, notably of breech mechanisms from the 12-pdr. to the 8-in. howitzer; small arms, including Lewis and Vickers guns, shown in much detail; welded and other sheet-metal work for aircraft, and aircraft woodwork, with partly assembled framing for planes, and struts, propellers, and other joinery; and unclassified engineering work, including pneumatic tools, pulleys and gearing. In addition, there are considerable collections of tool-room work, including a variety of tools such as drills and twist drills, cutters, reamers and taps; drawing dies and punches, chucks and test pieces; projectiles, including shells, fuses, gaines and bombs; optical work, including rangefinders, binoculars and periscopes; and blown glassware, from incandescent lamp bulbs produced from the pot to surgical glass thermometers, Röntgen-ray tubes and other blow-pipe work. Many articles, such as the Clerget engine cylinder and some optical instruments, are shown in various stages of manufacture; and both in this way and in the detailed catalogue the specimens are supplemented by a great deal of valuable information exhibiting separately both the constituent parts that women make and the circumstances—material, tool, limits, time, extent of supervision—under which they make them.

To some extent the photographs cover the same ground, but even where they do so they add valuable indications of the actual processes and tools on which the women are engaged, and collectively show even better than the specimens the enormous variety of mechanical work that women are now doing. The largest group of photographs is devoted to the work of women in shipbuilding and mechanical engineering. One photograph, showing women running electric wiring on a warship, is interesting at the present time, when there is a great scarcity of skilled electric fitters, and the separation of electrical work into what requires real skill and experience from what can be done satisfactorily with short training, seems to be particularly imperfect. The large number of photographs showing machining operations on lathes, drills, boring machines, slotters, planers and shapers is a reminder of the variety of machining on marine work that women can do if men will employ them; and perhaps as instructive are the photographs of women working on large structures, such as tubular boilers, and on work at heights, such as painting ships' sides. Other notable marine work includes fitting and finishing details of engines, and operating and setting up centre lathes for themselves on non-repetition work. An interesting collection is that which shows the large part women are taking in making turbines, from trimming the individual blades to building up the rotors. Allied to the photographs of marine work are those of constructional and general engineering. Here, for instance, women are seen doing a variety of operations on the construction of bridge girders; marking out, drilling with power and hydraulic machines and with pneumatic drills, holding up, acting as fitter's helper in assembling girders, hydraulic riveting, punching and shearing, besides a variety of machining on plates and of miscellaneous work, such as painting and general labouring. In boiler work, again, they are seen planing and bending plates, hydraulic riveting flues, boring shells, drilling flue flanges and end-plates. In locomotive work, besides marking off and a variety of non-repetition machine jobs in which they set up for themselves, they are turning locomotive wheels and doing a number of minor fitting jobs. Other work, not to be seen in the specimens, is shown in the photographs of the considerable amount of work women are now doing in wire and rolling mills; in the chemical and explosives trades, from labouring and process work to laboratory estimations; and in the foundry in practically all operations except melting. They show also the facility with which they can drive cranes for all uses, their trustworthiness in taking charge of power plant, and their adaptability in doing a variety of repairs, such, for example, as those to automatic gas meters.

A section of peculiar interest in its promise for the future is that devoted to the exhibits of the Ministry's Instructional Factories and Training Centres. There are upwards of 50 of these factories now in operation in most of the large industrial districts; and exhibits are shown here from some 18 of them. The most complete in this exhibition is perhaps that of the Loughborough Technical Institute. Limitations of space make it impossible to describe fully what is shown in this exhibit, but it may be commended to the careful attention of manufacturers who wish to know what can be done by the women and discharged soldiers—for at these centres discharged soldiers are now trained as freely as women—who are turned out from such institutes week after week. They will see examples of oxy-acetylene welding on sheet metal and on cast-iron that would be admirable for the most experienced tradesman, and all produced by women who have had anything from a fortnight to six weeks' training. A piece of cast-iron welding, for example, done by a woman after a fortnight's training, would be quite unexceptionable by whomever it had been produced. From the aero-fitting shop specimens are shown of a large variety of sheet-metal fittings that women are making to drawings after a matter of anything from about a week to three weeks' training. Other examples are shown of woodwork in similar variety, and a complete wing of an "Avro" aeroplane is not only made in all its parts by women but completely assembled. In the gauge department examples are shown of master gauges, which the Institute makes for the National Physical Laboratory, made entirely by women except, curiously enough, the hardening, though they do such work often in other shops; and in machine work the product of every variety of machine is shown applied to the uses of almost all war industries. There are also some examples of fitting, such as parts of optical indicators for aero-engines; and an exhibit, notable because it belongs to a branch of work into which women seem to have had much difficulty in securing entrance, is that of pattern making, of which many specimens are shown. Perhaps the most instructive fact in connection with this exhibit is that the entire operative staff of the institution, numbering over 600 people, including its tool-room, is composed of its own pupils. It could not have been easy work for the instructors at the outset to work a large establishment with so complete an absence of experienced labour and so constant an influx of inexperienced newcomers; and the fact that they have been able to do this, and are carrying on with an increasing output of pupils, is the best evidence of the completeness with which women and discharged soldiers can be adapted to industrial work, if the care and trouble are taken to train them in the right way.

The proviso is specially important in the case of discharged soldiers, not only because many of them have to learn shop habits as well as shop practice, but also because they represent a huge moral obligation of the community which at present it seems a long way from discharging. The fault may technically lie with the discharged soldier, for on paper the arrangements and allowances for his training are liberal as compared with what is done in other countries or has been usual in the past; but the fact remains that, whoever may be at fault, the loss is the country's because, in so far as it does not succeed in attracting discharged soldiers, it is both failing in its obligation and losing what should be a valuable present source of productive power. The Ministry of Munitions with great wisdom and sympathy has given manufacturers to understand that for the purposes of dilution it regards the employment of discharged soldiers as equivalent to that of women. Experience after the Boer War confirms what has often been found during the past three years, that to be efficient workmen discharged soldiers need a preliminary shop training before they are actually launched into commercial work. The provisions for giving this training shown in this exhibition are admirable in quality; but in quantity and in the means of attracting the right men they seem still to be in their infancy if the best use is to be made of this labour. Mr. Kellaway said that about 500 women are being turned out from these schools every week, and between 40,000 and 50,000 had been turned out in all. Apparently this figure includes discharged soldiers, who can only be a small fraction of it; and it is plain that, even making allowance for the firms who have instituted systematic training shops of their own—an enterprise most highly to be commended, but probably more suitable to the training of women than to that of soldiers newly home from war and hospital—the total provision for training these men can only be touching the fringe of the numbers who are available for such training, if they were taught and the training facilities provided on a large enough scale.

It must be conceded that without serious exaggeration the Ministry of Munitions may be said to have compiled in the specimens and photographs of this exhibition a dictionary of war manufactures. The utmost credit is due to their technical staff for so admirable a result, and it is to be hoped that in their further exhibitions and in future editions of their catalogue they will not be weary in well-doing, but will contrive to present the information they have collected with increasing fulness. The exhibition, indeed, is the physical complement of the vast figures in which the aggregate amount of women's work has so often been expressed by official speakers. But, proper though it may be in due season to praise famous men and to magnify their achievements, the question that this exhibition suggests at the present time is not so much how far women and discharged soldiers have already contributed to maintain industrial production as how far their powers are being used as fully as this exhibition, among other evidences, shows that they might be.

This question suggests itself all the more because evidence continues to accumulate tending to show that the limit of the utilisation of this asset of production is far from having been reached. As we had occasion recently to point out, our visit to the Birmingham district showed an extensive use of woman power, not perhaps comparable in its variety to what is represented in this exhibition, but sufficient to confirm the belief that the exhibition represents regular practice and not picked or isolated specimens. But the use of women shown in these factories was no less notable for the fact that operations done by them in one shop were wholly confined to men in another, where, nevertheless, women might be employed on other work. The absence of women from most tool-rooms, for instance, seemed difficult to explain in the face of some of the work they were doing in other departments; and the Loughborough exhibit of work of the highest accuracy made with a tool-room of which all the operatives had been only a few months in training and by workers who were constantly recruited with raw and inexperienced hands to fill the places of those who were passing out into industry, is a practical proof that the exclusion of women from tool-rooms can in most cases be due only

to timid management, inexpert foremanship, or reasons even less tolerable.

What we saw at Birmingham is, moreover, confirmed by reports that have repeatedly reached us from other centres and by criticisms such as were made at the recent meetings of the Institution of Mechanical Engineers. Manufacturers who have been, and are still, at the pains and outlay of introducing women are discouraged when they find other manufacturers who decline this share of the common burden, and yet neither in orders, men, or material seem a penny the worse. Still more trying is the case of those who find, as some complain, that their men leave them at the first opportunity in order to get employment with a firm engaged on Admiralty contracts, because the men of such firms are protected by the Admiralty against being recruited, even when they are employed on work that women could do and are doing elsewhere. Complaints to this effect are made not at random but with chapter and verse. It is said, for instance, that in one great shipyard the exclusion of women is carried out with such ostentation that not a single woman appears on the pay-roll, even as a clerk or a cleaner. The demand, again, as we noted above, for really skilled electrical fitters for work that inexperienced hands cannot do is very acute; yet skilled men seem able to find employment in many yards on work that women are doing wholesale in other establishments.

Monitus multumque monendus, the Ministry of Munitions would add to the excellent service that it is doing by these exhibitions if it would procure the firms under its control, and the other departments of the Government under whose wings firms take shelter, to live up to the standard of labour economy that the exhibition discloses. No one would wish to jeopardise any part of the output of munitions in order to contribute men to the Army. But, as Mr. Kellaway observed in opening this exhibition, the only ground for protecting men against recruitment is that they are indispensable and irreplaceable. There is no ground for the suggestion that if they are replaceable in one shop on a given class of work, they are not to be replaced in another; or that women can do work efficiently and admirably if it is destined for the use of the Army, but must be excluded from work which mechanically is exactly similar if it is done for the Admiralty. While distinctions such as these continue to engender heart-burnings among manufacturers, their wholehearted co-operation in making the fullest use of woman labour cannot be expected; and without that co-operation and that complete employment of our fullest productive assets the Army, to adopt Mr. Kellaway's expression, must be "let down" either in men or munitions.

THE BRITISH GLASS INDUSTRY.

APPARENTLY a very uniform, simple substance, glass is really a complex compound which has to undergo severe treatment before it acquires its valuable properties, and which subsequently marks its resentment of this treatment by its peculiarities. It is transparent, readily takes a high polish, and possesses considerable strength and elasticity; but it may distort objects seen through it, it is easily overstressed, and breaks and cracks with unpleasantly sharp edges. Although an insulator under ordinary conditions, it conducts heat and electricity when hot. When the members of the Society of Glass Technology, on Wednesday, May 15, discussed the Future of the British Glass Industry, with special regard to the time just after the war, they gave the indifferent spectator the impression that they resembled in some respects their own product. All glass is made in a pot; but the difficulties of the manufacture of optical glass do not worry the glass-bottle maker, and the commercial interests of the window-glass manufacturer and of the chemical glass trade diverge widely. The electricity of the enthusiasm of some members who insisted upon their all pulling together, hardly communicated themselves to others whose aspirations would be satisfied with the privileges of a key-industry in a dump-proof Empire. While welcoming State aid to strengthen them against the stresses of foreign competition and labour claims, they resented the stress of Government interference. There was some plain speaking, which generally does good. The discussion focussed the problems of the glass industry for the glass technologists and the representatives of numerous Government departments, present at the big gathering, some distorted images and views were corrected, and a far-going—in a sense aggressive—resolution was withdrawn as such and toned down into a circular, to be submitted to members and to be voted upon at a future meeting.

The British glass industry has reason to put its house in order. The once prosperous business was inefficient at the outbreak of the war, and while the war has raised it to a stage of efficiency, it is feared it may break down with the conclusion of the war. That the country at the beginning of the war hardly produced more than 20 per cent. of the glass it wanted was less serious than the fact that absolutely indispensable kinds of glass, like chemical and scientific glass, were not made here at all, and could not be made at once. There were no furnaces, no trained hands, no raw materials. By united efforts those wants have been met. "We have in three years already beaten the German in some lines, though not in all lines," Mr. Baird, of Messrs. Baird and Tatlow, Hatton Garden, E.C., said, and this at a time when the State made ever-increasing demands for all sorts of glass, not only for munition works, machinery and instruments, but also for common tableware, bottles, jugs, lighting, &c., and when the trained boys were called up as soon as they had become useful. The demand for glass would, he continued, grow after the war, the general industrial development would require more research and laboratory apparatus and, not to be attacked in the rear from abroad. The British glass industry needed foster parents and the care of a department such as the Research Department of the Ministry of Munitions.

The fear of foreign competition seemed to be generally shared in the meeting. Mr. J. Connolly feared the low Continental wages which made dumping possible. Mr. S. M. Jenkinson, of the Edinburgh-Leith Glass Works, admitted that the glass industry was not generally efficient yet. The glass-makers could not ask the Government to bolster up an inefficient industry; but they were becoming efficient, and their Society of Glass Technologists was unique in so far as it represented, in its 330 members, the united interests of employer and employed.

The general policy and the measures to be adopted to meet the threatening critical times were outlined by Mr. Wood in his opening remarks. Last year at Sheffield he had suggested an organisation of the glass industry on the lines of the Industrial Councils proposed by the Whitley Parliamentary Report. Distinguishing eight sections of the glass trade: table and decorative glass, plate and window glass, optical glass, chemical and scientific glass, glass for lighting, pressed glass ware, common bottles, flint glass bottles, he would form a glass trade council consisting of four representatives (employers and employed) of each section, and add 12 independent members (six from the Government, and two financial men). The main thing was to pull together; they would then be in a position to demand the necessary Government support. He would entrust the care of their industry to the Optical Research Department of the Ministry of Munitions, which he hoped would continue after the war; that department was fully acquainted with their needs and difficulties; he was not in favour of a new organisation under the Reconstruction Department, which had no information so far as to their aims. In this suggestion he certainly seemed to have the majority of the members with him. Mr. Biram, of the Ministry of Munitions, was quite ready to acknowledge the glass industry as a key or pivotal industry in the sense of the report of Lord Balfour of Burleigh's Committee, *i.e.*, an industry to be maintained and defended at all hazards and expense, also by custom duties. Assistance was needed, Mr. Biram said, not only because the cost of labour was high over here; but the most difficult times for labour were still ahead.

As regards subvention, Sir Frank Heath, of the Research Committee, explained that the Government had set aside 1,000,000*l.* for the encouragement of science, that there were 40,000*l.* at the disposal of the glass industry, and that, while in general they were ready to grant 1*l.* in aid per 1*l.* expended, they were, in the case of a key industry like glass, prepared to raise the grant rate to 9*l.* But those grants were limited to the five years to come, and they were subject to conditions, though those stipulations were not to be interpreted by the letter. The chief point was that the grants were to be delegated to the trade associations, provided the latter were not run for their own jobs. Glass technologists need not fear that the department desired to control industrial research; that would be impossible, even if they intended it, for the work had already grown beyond their own power. Mr. McGegan stated that the Government did not desire to make any such organisation as the Whitley Council compulsory, nor was the Reconstruction Department to interfere with the industry from the manufacturer's point of view; the latter department would, moreover, come to an end a year after the war.

These statements did not fail to influence the members as to the long resolution which Mr. Jenkinson had submitted at an early stage of the discussion: That the Optical Research Department of the Ministry of Munitions should continue to remain in existence after the war, and that the Optical Glass Ware Council be charged with the supervision of the industry. The resolution further called for the prohibition of glass imports, except by permit, until the industry be firmly established, in this country, and practically—though not in these words—declared that the society did not desire interference by the Reconstruction Department. Mr. Butterworth and others at once remarked that the resolution really embodied something like ten resolutions, copies of which were to be forwarded to all the official departments, although members had had no notice of what they were to vote upon, and the meeting wisely decided to communicate the resolution as a circular to all the members for deliberation and discussion in due course.

The solidarity of the glass interests had been accentuated by various speakers, mainly also by the scientists, Sir Herbert Jackson (who declared himself to be an optimist as to the future of the British glass industry) and Dr. W. Rosenhain. In desiring that information should be placed at the disposal of all the workers as well as of the heads, these speakers drew attention to the good example given by the Ediswan Company which, that very morning, had opened all parts of their works to members of the society; that was a step in the right direction. But upon this point, and upon the further question, which of the many fundamental industries of the country—all essential to the great structure and interlinked, though not in the sense of the proverbial single chain, which is no stronger than its weakest link—are to rank as key industries entitled to State subvention, opinions will take a long time yet to settle and to crystallise.

NOTES.

THE STRENGTH OF PLATE SPRINGS.

IN a paper published in a recent issue of the *Journal of the Franklin Institute*, Messrs. D. Landau and P. H. Parr give the results of an investigation into the theory of plate springs made some years ago, but not then published. The theory developed was, however, adopted in practice by one firm, and led, it is stated, to a very substantial increase in the endurance and carrying power of this type of spring. Ordinary leaf springs, the authors' state, always fail at the shortest leaf, although the maximum stress is supposed by their designers to be the same for each leaf. In a two-leaf spring, for example, it has been usual to make the short leaf half the length of the upper leaf, and it was assumed that under load both leaves were equally stressed. The authors of the paper under review state that in actual practice the short leaf bears on the long leaf at its ends only. The combination is really statically indeterminate, and applying the usual methods of determining the stresses in such structures, it turns out that the lower leaf is much more heavily stressed than the upper one. In fact, with the lower leaf one-half as long as the upper

one the combination is only 1·6 times as strong as the upper leaf taken separately. A three-leaved spring designed on the same lines is only 2·207 times as strong as the single, unassisted upper leaf. The corresponding figures for four-leaved, 10-leaved and 20-leaved springs are 2·817, 6·503 and 12·689, in place of 4, 10 and 20, as is frequently assumed.

REINFORCED CONCRETE SHIPS.

In the course of a paper which he read on May 9, before the Concrete Institute, Mr. A. Alban H. Scott stated that the loose application of the term "concrete poured in" should be combated. To obtain the best results, concrete should be placed into position as dry as possible, and after the concrete has been so placed and sprinkled with water the result is a material much stronger and much more waterproof than a wet, sloppy mixture, or even a mixture which might be termed plastic; for this reason one would much sooner adopt the method of elevating the practically dry, mixed material in preference to delivery by gravitation. In reinforced concrete, one should not look upon the concrete work as a plastic material that can be poured, but rather as a dry material that has to be raised to efficiency by the admixture of water in small doses after the dry material is in its final position. The centering for the outside of the boat can be in large units, but for the interior of the boat the units have to be comparatively small, as it is necessary that the concrete should not be "poured" from a great height. This will allow the centering on one side to be built up as the concrete is placed in position, so that efficient ramming and punning is ensured. Wherever possible concreting should be proceeded with as one complete operation, thus requiring day and night work with careful organisation. The steelwork should be as far as possible completed with the outside centering to one side of the internal beams and frames placed in position before the concreting is commenced. With judicious arrangement of the internal strutting this can be achieved, and where it is necessary for the concrete operation to be temporarily suspended, special care is required and special precaution rods must be inserted at such junctions. It has not been found advisable to use neat cement grouting at these joints in the concrete. With the thin protecting coat of concrete that obtains in reinforced concrete boat work, it is necessary, both from a structural and fire-resisting standpoint, to have the steelwork well tied in, connected double-mesh work where possible, and extra care taken at all junctions; all arrises should be rounded or splayed. Properly designed and erected reinforced concrete work has undoubted claims over unprotected steel construction, and in arriving at the rate for insurance against fire, the underwriters ought to take this into account; on the other hand, however, with grain cargoes any effect from swelling would have a more serious result on reinforced concrete than on steel owing to the steel boat having a greater elasticity.

THE NON-FERROUS METAL INDUSTRIES.

The smelting of non-iron metals will be under Government control during and for some time after the war, with the special purpose of securing an adequate supply free from enemy control. This involves some supervision of all mining, refining and trading in these metals within the kingdom, and the conditions of this control are defined in an Act of Parliament just published, the Non-Ferrous Metal Industries Act, 1918. As there may be a certain amount of similar legislation we give an outline of the method of supervision. The metals and ores to which the Act applies are zinc, copper, tin, lead, nickel and aluminium; "ore" includes concentrates, mattes, precipitates and other intermediate products; the Board of Trade may, by formal Order, add any other non-ferrous metals or ores; manufactured metal products are not included unless prescribed; purchase or sale of metal is not included where the transactions are only incidental to the carrying on of a business. A licence is required, from August 6, 1918, to carry on the business of winning, extracting, smelting, dressing, refining or dealing wholesale in the metals or ores mentioned. The conditions of a licence are that the licensee is free from enemy control. An "enemy" is any one who is or has been a subject of a State at war with this country on February 6, 1918. "Control" of a business applying for a licence is very elaborately defined. An "enemy" director, partner, manager or principal officer; a company of whose capital any was held on or after November 12, 1917, or of whose stocks or shares any was the subject of a custodian order under the Trading with the Enemy Acts; or a business directly or indirectly subject to enemy "influence or association"—are excluded from holding a licence. Shareholders must be registered, share warrants to bearer are not allowed, any company may call upon any of its share or debenture holders to declare on oath the beneficial ownership. The very elaboration of these definitions reveals the awkward legal problems that must arise, and these may be referred to the High Court in the form of specific questions as to whether A. is an enemy or B. is under enemy influence, &c. Books and documents must be produced on the application or after the grant of a licence for examination by the Board of Trade for the purposes of the Act and the Court may decide whether such production has been sufficient. Two judges must try the issue, but there is no appeal from their decision. For the general carrying into effect of the Act the Board of Trade may make rules. The supervision does not extend to the industrial operations of a licensee: it is directed solely to excluding enemies from owning or controlling the capital or managing the business. The Act applies during the war and for five years after. The licence costs 21s., nominally, and runs without renewal, but is subject to revocation. The sooner application is made the better in order to find out and comply with the practical form in which the Board of Trade may state the requirements of the Act. The mere fact of owning some shares in an enemy business does not appear to disqualify for a licence unless it amounts to the holder being subject to direct or indirect enemy influence or association in the conduct of his business, but to this there is a definite exception, viz., if a company, firm or person, at any time after November 12, 1917, had an interest of one-fifth or more in any home or foreign undertaking in which enemies were also interested to the extent of one-fifth or more, disqualification follows. In this case "interest" means an interest in the "capital profits or voting power." The difficulties are that everything, however definite it seems at first reading, turns finally on the elements of influence and also that the directors of a company do not always know what other interests their shareholders may have, even a large shareholder, especially if he takes no direct part in the management.

MOLECULAR SURFACE ENERGY.

The molecular surface energy of liquids is one of the most important properties, but difficult of exact determination. The fundamental work on this subject was done by Eötvös and subsequently by Ramsay and Shields, and others; but the experiments were confined to small temperature ranges. Professor F. M. Jaeger, of Groningen, Netherlands, therefore, worked out a method enabling him to study the phenomena within the range from — 80 deg. C. up to + 1,650 deg. C. Having presented during recent years several communications on his researches to the Akademie Wetenschappen of Amsterdam, he published last November a full account in the *Zeitschrift für Anorganische Chemie*, vol. ci, pages 1 to 124. He deals with about 200 organic compounds of very varied constitutions, and some fifty inorganic compounds. In the case of the organic compounds he could not go beyond 250 deg. C. lest decomposition occur; some of the inorganic salts, *e.g.*, alkali borates, which are very stable, were tested up to 1,650 deg. The methods available for his investigation, surface tension, liquid jets (Rayleigh), oscillating drops (Lenard), capillary waves (Kelvin), capillary rise, &c., were not suitable for extreme temperatures. Jaeger's method, which he first tried when working in the Geophysical Laboratory of the Carnegie Institution at Washington, is to produce a bubble of some inert gas (pure nitrogen) at the end of a capillary tube just dipping into the liquid, and to determine the bursting pressure of this bubble. Elaborate and delicate apparatus are required. Glass vessels and capillaries could only be used in some cases; in the others, vessels and capillaries of platinum-rhodium are needed. The end of the capillary has a width of 0.5 mm., and its edge must be kept sharp; bubbles are passed through the capillary until the pressure, at the pressure gauge, keeps constant; the growth and bursting of a bubble takes from 30 seconds to 50 seconds. The connection between the capillary and the other parts is made through several spiral tubes of platinum and aluminium to meet expansion effects, and octane, a hydrocarbon of the paraffin series, is introduced into the gauge to prevent corrosion of the mercury by the vapours. The quantities determined are the density d of the liquid; the surface tension $\chi = r\,H/2$, in ergs per square centimetre, where r is the radius of the capillary and H the bursting pressure in dynes; the molecular surface energy $\mu = \chi\,(M/d)^{\frac{2}{3}}$ (according to Eötvös) where M is the molecular weight; and the temperature coefficient $d\,\mu\,/d\,t$. For normal, *i.e.*, not-associated, liquids $d\,\mu/d\,t$ should have the constant value of 2.25 ergs per degree Centigrade according to Van der Waals; this is only partly confirmed, and it would appear that the surface energy must partly be kinetic in nature. Walden's rule, that the quotient: molecular cohesion/melting-point T, should be 3.65, and the quotient: molecular cohesion/boiling-point, should be 1.15, is found not to hold more than approximately either. Chemically, many of the results are very interesting. In a series of related compounds, such as alcohols, esters, &c., the μ increases in general with the molecular weight; unsaturated compounds have higher μ than the saturated compounds; aromatic para-compounds have greater surface energy than meta and ortho-compounds; and many stereo-isomerides differ strongly in this respect. It is also noteworthy that the μ/t curves of anisotropic liquid consist of two branches, a sharp minimum marking the point where the substance passes from the anisotropic (liquid crystal form) into the normal liquid state. On the other hand, the surface tensions of alkali halides decrease as the atomic weights of the metals and of the chlorine, bromine, &c., increase, and there are many irregularities.

YEAR-BOOK OF WIRELESS TELEGRAPHY AND TELEPHONY.—The second issue of this important publication, which runs to 1,150 pages, has appeared, and it furnishes abundant proof of the importance and extension of wireless telegraphy. The text of laws and regulations current in different countries occupies 463 pages. The "Land and Ships' Stations" section, which records the Call Letters and general particulars of wireless installations all over the world, has been made as complete as circumstances allow. Special articles appear from the pens of Dr. J. Ambrose Fleming, of Dr. Balth van-der-Pol, and of David Sarnoff, secretary of the Institute of Radio Engineers, U.S.A. Dr. N. W. McLachlan writes on "The Magnetic Behaviour of Iron in Alternating Fields of Radio Frequency," and Mr. A. R. Burrows on "Wireless Possibilities." The "useful data section" covers 150 pages and includes definitions of terms used in wireless, dictionary of technical terms, useful formulæ and equations, and many other things of much interest. The volume is issued by the Marconi Company, at Marconi House, Strand, London.

AMMONIA AND AMMONIACAL PRODUCTS.—Under an Order of the Minister of Munitions dated May 17, no ammonia or ammoniacal product may be manufactured or supplied after June 1 except under licence. No licence is required, however, to manufacture (*a*) crude ammoniacal liquor or sulphate of ammonia; (*b*) any other ammoniacal product provided the quantities do not exceed ½ ton in any month; or (*c*) to supply not more than 56 lb. of anhydrous ammonia or 1 cwt. of ammoniacal liquor or any ammoniacal product to any person during one month. Any instructions given with a view to avoiding loss or waste must be complied with, and such returns as may be required made. "Ammonia" means anhydrous ammonia and ammonia in aqueous solution: "ammoniacal products" means all compounds of ammonia and mixtures of preparations containing ammonia; and "crude ammoniacal liquor" means an aqueous solution of ammonia containing not more than 5 per cent. of ammonia. The Order does not apply to sulphate of ammonia, but under the Fertilisers Prices Order, 1918, licences are required for certain sales and deliveries of sulphate of ammonia, and in particular for all sales of sulphate of ammonia for use in the manufacture of munitions of war or for other industrial purposes. Applications in connection with the Order should be addressed to the Ministry of Munitions, Department of Explosives Supply, Storey's Gate, Westminster, S.W. 1, and marked "Fertiliser Section."

INDUSTRIAL NOTES.

THE Director of the Department of Labour Statistics, dealing with the labour market, in *The Labour Gazette*, states that in April the only industries in which there was any large number of workpeople employed less than full time were the textiles. In other trades full time, and in many cases a considerable amount of overtime, was being worked. The further withdrawal from industry of men for the Army has greatly increased the opportunities of employment for women, who can adapt themselves to new kinds of work.

Trade unions with a net membership of 1,063,564, excluding those serving with the forces, reported 9,991 (or 0·9 per cent.) of their members as unemployed at the end of April, compared with 1·2 per cent. at the end of March and 0·3 per cent. at the end of April, 1917. The increase in the percentage as compared with a year ago was almost entirely due to the cotton industry, in which the "unemployment" is in the nature of short time—the operatives affected not being discharged, but merely suspended in rotation for one week out of four or more, according to circumstances.

Of the 3,797,223 male and female workpeople insured under the National Insurance Acts, 1911 to 1916, the number unemployed at the end of April was 36,412 (or 0·96 per cent.), compared with 1·01 per cent. in the previous month and 0·63 per cent. a year ago. For males and females separately the percentages unemployed at the end of April were 0·39 and 2·21.

The principal increases in wages granted during April were a further advance of 4*s.* a week to railwaymen engaged in the manipulation of traffic, making in all an increase over pre-war rates of 25*s.*; bonuses on earnings of 12½ per cent. to time workers and 7½ per cent. to piece workers to men on munitions work in the building trades in England and Wales; and increased war wages to woollen and worsted trade operatives in Yorkshire varying from 10 per cent. to 12½ per cent. on the pre-war rates. Numerous increases were also made in hourly rates of wages in the building trades, including a general advance of 1½*d.* per hour (subject to a maximum war increase of 5*d.* per hour) for various occupations in a large number of districts in Scotland.

The number of disputes beginning in April was 57, and the total number of workpeople involved in all disputes in progress was 19,100 as compared with 46,900 in the previous month and 25,500 in April, 1917. The estimated total aggregate duration of all disputes during the month was 128,300 days as compared with 276,200 days in March 1918 and 82,900 days in April 1917.

The Commonwealth statistician states that the 444 strikes in Australia last year affected 1,941 establishments representing 173,970 workpeople, who had 4,689,316 workless days and a loss of 2,641,753*l.* in wages. Industrial disputes in New South Wales totalled 296 in Victoria 52.

Professor Murdoch, of Sydney University, thinks it likely that large numbers of young Japanese who went abroad, mainly to America, to study trade, will now be attracted to Australia.

The arrangements for our supply of zinc during and after the war are explained in a recent official report. The State agrees to take a minimum of 100,000 tons per year of Australian concentrates, with an option on 50,000 tons more, and to provide capital for the erection of two zinc-smelting works in this country. The State also agrees to advance capital for smelting works in Australia and to buy the zinc product up to a maximum of 45,000 tons per year for 10 years. A supply of Burmese concentrates is also secured, to be smelted in the British works. The companies controlling the Australian and British works are to repay the capital advanced by the State within a prescribed time. The British company is bound to purchase zinc ores mined in this country, on reasonable terms.

According to the report of the Committee on Industrial Policy, fine limit and screw gauges were made in this country before the war by the firms using them and were manufactured for general sale by "one small firm" only. The principal manufacturing country was the United States and the second Germany. The firm referred to is by no means a small one, and turned out first-class work. That the gauges made by firms for their own use were, generally, fully adequate in quality is proved by the fact that in all branches where we had a trade the work produced was unexcelled in the world market. The committee make no proposal on this matter except that the State should in future "take steps to secure the maintenance of an adequate supply" and provide a stock of special types for war work.

The suggested duties and powers of the Special Industries Board, proposed to be set up after the war, should receive careful attention from engineering firms. The Board is to be permanent, with a staff of officials and technical experts. It is to watch the course of industrial development and frame schemes for assisting industries producing "commodities of the special character" known as "key or pivotal," the examples cited being synthetic dyes and spelter. No State grants or subsidies are to be given to any industry except on the recommendation of the Board. Where State assistance or protection is given the Board is to see that the production of the favoured commodities is adequate in quantity and reasonable in price; and, for these purposes, it is to have powers of inspection and the right to examine manufacturers' books and cost accounts. It is also proposed that the Board should have power to deal with labour conditions and enforce its "decisions." Any article deemed "essential for national safety" may be included in its scope.

The effect of machinery in cheapening the production of bread has created a problem for the Committee of the House of Commons which investigates and criticises expenditure. The food control scheme secures to all bakers, large or small, the same quality of flour (and other matter of which bread is now made) at the same price—a price nicely calculated to give every baker a fair profit on the sale of his bread at 9*d.* per 4-lb. loaf. In the result, however, the small bakeries can hardly afford to sell at 9*d.* while the "highly efficient bakeries" make profits so large that the committee regard them as excessive. It appears from the report that the cost of baking bread in the small bakeries is 25*s.* per sack of flour, and in the large mechanical bakeries 10*s.* per sack of flour. In other terms the committee state the baking cost as 3*d.* and 1¼*d.* respectively per 4-lb. loaf. It is also stated that "four-fifths of the bread is made by one-tenth of the bakers"—presumably bakery owners and not working bakers are meant. The proportions indicate that a highly efficient mechanical bakery has an output equal to at least 40 average bakeries of the small class. Making full allowance therefore it would pay to erect a mechanical bakery in any area in which there are now from 40 to 100 small bakeries. A greater centralisation of production seems to pay better, as many large firms can spend ¼*d.* per loaf on distribution by bread vans and still make a good profit. The committee suggests that the price of flour be raised 5*s.* per sack, but this would only increase the hardship of the small baker. A similar problem has arisen in the rolling mills and is there dealt with by supplying pig-iron at a cheaper rate to mills with antiquated plant. In that case the Government wanted the old plant set to work and decided to pay an indirect bonus. What flour is to bread, so pig-iron is to steel. If any kind of inferior machinery must be used the best way is to treat the matter frankly by appraising the difference and paying for it in hard cash.

Writing to *The Times* in reference to the shortening of working hours generally, Mr. J. Fletcher Toomer, M.Inst.C.E., says that he was the engineer in charge of the construction of the 6½-mile tunnel for the drainage of the Valley of Mexico, where it was of vital importance for ventilation and drainage reasons that the bottom heading should be driven through in the shortest possible time. The Mexican 12-hour shift was reduced to 8 hours, and that again to 6 hours, which eventually was reduced to 4 hours, which was maintained until the heading was finished. The following statement will show the advantages gained in the reduction of working hours from 8 to 4 and a six-day week:—

Hours Worked in each Shift.	Average Cost per Metre. dols.	Average Number of Lineal Metres Driven each Week.
8	41·75	36
6	41·52	50
4	39·57	70

A point of the greatest interest centres in the fact that, although the number of metres driven by each man in each week was practically the same in the 8-hour shifts as in the 4-hour shifts, the men on the 4-hour shifts accomplished the work in half the time employed by those in the 8-hour shifts, thus doubling the total amount of metres driven in the week without increasing the cost of driving—in fact, slightly decreasing it. There was always a rush of workmen asking to be allowed to work on the 4-hour shifts. Naturally, with the shortening of the time of the completion of the heading there was an enormous saving in standing charges, such as general expense, pumping, winding, ventilation, &c. Mr. Toomer asks it to be understood that he is not advocating that all working shifts should be reduced to 4 hours. The work above-mentioned was of the heaviest kind, carried out under the exceptionally trying circumstances of wet and cold.

The Minister of Munitions has appointed a committee with the following terms of reference:—"To advise the Minister upon the general principles to be adopted in carrying out the Welfare and Health Work of the Ministry and to report to the Minister in all matters connected with the same, which may be referred to them by him from time to time." The secretary to the Committee is Mr. R. H. Crooke, 53, Parliament-street, S.W. 1, to whom all communications on the subject should be addressed.

THE ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 15th inst., at the Society Rooms, 70, Victoria-street, Westminster, Sir Napier Shaw, F.R.S., president, in the chair. Mr. C. E. P. Brooks, M.Sc., read a paper entitled "*Continentality and Temperatures. Second Paper.*" The first part of this paper deals with the variation with latitude of the coefficients which give the influence of land on temperature. Land east, land west and ice are considered separately, and it is found that in the tropics the coefficients are uniformly small. In the temperate regions in winter the effect of land to the east is also small, but land to the west has a well-marked effect in lowering temperature; this effect increases towards the poles. In summer, land both east and west increases temperature. In the second part the temperatures of land and water hemispheres are calculated. The distribution of land and sea at the beginning of the Great Ice Age is then reconstructed from geological data, and on applying the formulæ calculated in the first part to this changed distribution, it is found that the temperature must have been lower than the present in different districts by various amounts up to 20 deg. C. in January and 15 deg. C. in July. These changes agree very closely with those required by geologists and palæontologists, and it is further proved that the glacial period was a necessary consequence of the geographical changes. Finally, a theory of climatic evolution is outlined in accordance with these ideas and the theory of isostasy.

The Report on the Phenological Observations in the British Isles during 1917 was presented by Mr. J. Edmund Clark and Mr. H. B. Adames. The persistent winter, hardly broken over 4½ months from early December, dominated seasonal conditions. December to April averaged, in England S.W., a deficiency of 4·8 deg. F., from which it ranged to — 1·2 deg. F. in Scotland N. In the southern half of our islands the 125 days to mid-April were cold almost beyond precedent in the previous 100 years, farm and garden prospects being therefore of the gloomiest. Yet by the end of spring there was a complete change; England, the chief sufferer, having an excess of 3·5 deg. Absence of keen wind and frosts favoured the belated blossoming, and by June flowering dates were normal, although the early spring flowers, anemone and blackthorn, had been 20 days and 24 days late. From the time of the dog rose on, dates were actually early. Finally, the chief practical result of the cold was indirect, the heavy destruction of bird life favouring tree blight and caterpillars, the ova of which were preserved by the unbroken cold. In many parts the latter stripped fruit trees and ruined garden greens So, too, the Antler caterpillar plague in Derbyshire was ascribed mainly to the scarcity of rooks. On the other hand, berries and other fruits suffered little from birds. Other summer broods than garden white grubs were also favoured, especially Vanessidæ, including such rarer forms as the Comma and White Admiral. From late July into September the splendid harvest prospect were much marred by rain, wind and lack of sun. First results were better than 1916, although grain crops fell some 5 per cent. below the ten-year average in England, rising, however, above elsewhere. As to roots, a warm, dry November more than made up for the cold, wet October, whilst potatoes gave a record crop with 8,600,000 tons off 1,364,000 acres, compared with 5,468,000 tons off 1,134,400 in 1916. Tree fruits, too, gave excellent returns, the August gales proving prejudicial to apples only. Finally, November gave a splendid send-off for the coming year in the exceptionally favoured winter earring of the grain crops. This, our president, Sir Napier Shaw, has shown may be counted as half the battle in the prospects for successful harvesting Table V of the report gives the yearly floral means for the five chief districts from 1891. That year alone was, later than 1917, namely 9·6 days, against 7·6 after the mean flowering date May, 17·4. Birds and insects, in Table VI, confirm the lateness of 1917, averaging 6 days and 12 days behind, whilst Table VII, of 24 migrants, shows nearly 10 days' lag behind a twenty-year mean, 1877–96. We may, indeed, be thankful that farm and garden produce came out so much ahead of our fears.

FERRO-CONCRETE MOTOR BOAT.—The first 1,000-tons deadweight concrete motor boat was launched at Jernbetonskibsbyggeriet's Dock-yard, Gresaker, near Fredrikstad, Norway, on May 8. This is the first concrete boat in the world classed for oversea trade, besides being the largest concrete boat built in Europe to the present day. She is classed: "I.A.I. Betonlægter Experimental for carrying coal and timber" in the Norwegian Veritas. Her dimensions are as follow: Length, between perpendiculars, 170 ft. 3 in.; Breadth, exluding fenders, 31 ft. 10 in.; depth, 18 ft. Her carrying capacity is about 1,000 tons deadweight. She has four watertight bulkheads, two holds and two large hatches (26 ft. by 13 ft.). Accommodation for officers, crew, &c., is placed in the poop and in the forecastle. Her main machinery consists of two Bolinder motors of 160 h.p. each.

REFRACTORY MATERIALS SECTION OF THE CERAMIC SOCIETY.

THIS important branch of the society held its fourth meeting on May 14 and 15, when a large gathering of members from all the chief industrial districts of the kingdom assembled at the University of Sheffield. The president, Mr. W. J. Jones, Deputy-Controller of Iron and Steel Production (Ministry of Munitions), occupied the chair.

The first paper was by Professor Fearnsides, on "Native Supplies of Refractory Materials Available in the Sheffield District." This was a useful summary account of the local sources of valuable refractory materials, and included a survey of mineral substances derived from the carboniferous series down to glacial and post-glacial drift deposits, with special reference to the famous Sheffield ganister and associated fireclays, and the 25 miles outcrop of magnesian limestone (which rock contains over 95 per cent. of the mineral dolomite) at present worked only at Steetly, near Worksop.

Mr. J. Holland's historical "Notes on the Evolution of the Ganister Industry in the Sheffield District" followed, and related that the ganister was at first obtained from outcrops for use as road metal, and that later on road scrapings of such material was used for lining the holes of the crucible furnaces. Huntsman is believed to have been the first to use ganister in this way, some time between 1742 and 1772. Its use gradually extended in the steel trade until eventually mining had to be resorted to in order to furnish the necessary supplies. The first to manufacture ground ganister was Joseph Bramall, senior, of Oughtibridge, who, in order to imitate as closely as possible the road scrapings hitherto used, added to the ganister rock in his grinding mill a small proportion of fireclay and horse-droppings. It was the introduction of the Bessemer converter in 1856 which quickly developed the use of ground ganister.

Next came two papers by Dr. A. Scott on "The Constitution of Silica Bricks," and "A Micro-Study of Magnesite Bricks." The former opened with a discussion of the chemical and microscopic characters of the various rocks used in the manufacture of silica bricks. In Germany the chief rock is composed of quartz crystals set in an amorphous or cryptocrystalline silicious cement; in America, France and Sweden, quartzites are used; in this country ganister and other indurated silica rocks. One of the chief points is the rate at which the quartz can be converted by heat into the high-temperature forms, and this depends on various factors—grain size, amount and distribution of cementing material and nature of added bond. Quantitative measurements of amounts of unaltered quartz in various bricks as sold were given, the greatest degree of conversion being in the American bricks. The course of the conversion was discussed, the quartz being dissolved in the calcium silicate matrix and the silica reprecipitated as cristobalite. The microscopic appearance of various products used was described and the reaction between the iron oxides and the silica determined. Bricks from the ports of furnaces showed large development of fayalite, while in roof bricks the iron is mainly in the form of oxides.

In his paper on Magnesite Bricks, Dr. Scott referred to the description of bricks by Cornu. So far, two types of crystallisation of magnesia have been observed, one in which periclase forms a reticulate mass of polygonal crystals with inclusions of the spinel mineral magnesioferrite. Locally other impurities form a crystalline or glassy matrix, as in the other type of crystallisation. In the second type the periclase is in the form of rounded anhedral grains set in a matrix generally crystalline, but occasionally glassy. In the former, various minerals develop forsterite, monticellite, and an unidentified mineral resembling quartz but with lower refractive index. The increase in grain size with prolonged heating and consequent contraction was also discussed, as well as the question of the existence of magnesia in more than one form.

The last morning paper was by Mr. Alleyne Reynolds, on "The Essential Properties of Refractories used in Steel Production." This is a long paper, with appendices which altogether approximate to the length of the paper itself, and, unfortunately for the chances of discussion, these appendices (which Mr. Reynolds considers indispensable as affording proofs of his arguments) could not be printed in time. The author's contentions are largely based on Dr. J. E. Stead's elucidation of the nature of the Bessemer process, in which the carbon itself of the pig-iron mainly serves as the fuel, and he considers that the proper sequence of separate stages of steel refinement must be the sequence of reactions in the Bessemer converter. The order of oxidation is at low temperature, silico-manganese, silico-iron, carbon, phosphorus. At high temperatures silico-iron is not only not attacked, but is actually formed. Then the sequence is silico-manganese, carbon, phosphorus. In the basic process where phosphatic slags may occur (along with silicates) the carbon reaction merely requires high temperature, and is independent of the phosphorus reaction. Mass action of course has some influence. Thus the fourth process which the author insists on must be a treatment by silico-manganese.

The author maintains that whenever steel is produced low in oxygen content it is always due to the action of silico-manganese, either added or in the nascent state, and states that the best steel-makers add silico-manganese, instead of awaiting its formation from silicide of iron and carbide of manganese. Mr. Reynolds intimates that what is imperatively necessary is that in the final treatment of steel it shall not come in contact with acid material at all, because silica has an oxidising action on the iron. What is urgently required is a chemically inactive neutral material, and he suggests the possible production of neutral silicates of alumina as being likely to meet the case, or that silicate of magnesia (if it can be formed) would probably be an ideal material for the purpose.

Subsequent papers included the following:—

"Silica Products. I. Raw Materials," by Dr. A. Bigot.

"On the New Refractory and Abrasive Matter called Corindite," by Dr. A. Bigot.

"An Advance towards Greater Economy of Fuel and Increased Output in the Deadburning of Magnesite and Dolomite and the Burning of Cement," by Mr. E. Steiger. We shall publish this paper in a future issue.

"The Dissociation of Salt," by Mr. H. V. Thompson.

"Refractories in Gas Works from a User's Point of View," by Mr. J. P. Leather.

"The Standardisation of Tests for Refractory Materials (Part I)," presented as a report of the Special Committee, by Dr. J. W. Mellor, hon. secretary.

With reference to the "Standardisation Tests for Refractory Materials," the report was received with general approval, subject to some criticism that certain tests were not adapted for use in works' laboratories. As Dr. Mellor pointed out, tests which answer very well for works' laboratories are not always adaptable for standard tests. In a later report it is intended to deal with such subjects as corrosive action by slags, &c. Refractory linings for electric furnaces will also need much attention for future developments.

"Note on Electric Furnace Treatment of Refractories," by Dr. R. S. Hutton.

"A Note on a Firebrick from the Crown of an Electric Steel Furnace," by Mr. W. J. Rees.

In connection with the above meeting an evening lecture on "Science and the Practical Man" was delivered by Mr. Cosmo Johns, of which the following is an abstract:—

Never before have people been so intensely occupied in applying science to destructive and constructive purposes. Great departments of the state are now fully awake to the value of scientific methods. Technical societies never flourished as they do now. Practical men have heard of the virtues of science, and show all the enthusiasm of new converts. That is why the subject was selected.

The ability to make tests or use measuring instruments is not necessarily science. A youth can soon be taught to take accurate measurements of kiln temperatures, or read gauges, or carry out routine analyses, but all this would not make him a scientist. Science is the search for truth; it seeks an explanation of operations in the world of material things. Its impelling motive is the love of knowledge, the joy of discovery, and the approbation of the few who are competent to judge.

Discoveries are stated as laws, rules or principles. The laws of science are the milestones marking the progress of mankind from savagery to civilisation. There is but one science—pure science. Technology, sometimes erroneously called applied science, is simply the application of pure science to industry.

As a people we are rich in original discoveries in pure science, but we are weak in the applications of science to industry. A new law is always discovered long before any industrial application is found for it. Usually there is a long interval between a discovery and its interpretation, and another between that and its application.

Agriculture is the most important industry in any country. The monk Mendel, about 1866 to 1869, by cultural experiments, discovered the law known by his name, that the characters of plants can be crossed in accordance with a definite law. It attracted no attention until 1896, when it received notice, and in 1900 the subject was taken in hand at Cambridge University. Since 1914, through the application of Mendel's law, the east of England has been made green with the products.

Mining naturally comes next to agriculture as an industry. Haines, in 1860, observed the effects of oily substances in contact with certain substances. Carrie Everson, in 1886, patented a process for mixing oil and water so as to produce a froth by means of which valuable minerals could be floated up from poor ores or refuse material, but it achieved no commercial success. In 1900, mining men adopted this flotation process for separating valuable materials from refuse heaps, &c., all the essentials of the process appearing in Carrie Everson's patent.

Next to mining comes metallurgy. Willard Gibbs, in 1876, worked out and published his phase rule, but no attention was paid to it. In 1896 to 1900 it was brought to light again, and at the present time it is the foundation of all our studies. The same kind of sequence occurred in several other instances which were related.

Though not usually so regarded, the encouragement of pure science is the most remunerative investment for any nation.

The practical man has been stated to be one who practises the errors of his predecessors. Though largely true, it is like most witty sayings only partly true. It should not be forgotten that the practical man pierced mountains, bored under rivers, bridged estuaries, harnessed waterfalls, built railways, sent wireless messages, banished malaria, &c. Between the worker in pure science and the really practical man there is a kinship. They work on parallel lines, one extending knowledge, the other extending its application, and their efforts are co-ordinated by interpreters of science. These latter should be men who work in research laboratories, and should have a sound training in the principles of pure science.

Science is but organised commonsense; collecting facts, making careful observations, &c. It can only be applied when science is known. The mere technical training suffices for routine work, but for new and strange problems a knowledge of the principles of science is necessary, and the ability to apply them in industry.

The course taken at the Imperial College of Science and Technology is an example of the kind of training which meets the conditions indicated. On entrance, a high standard is exacted, two years are devoted to pure science, and two more years to technological studies. After such a training, a person engaged in a laboratory would be a research worker, and might be called a chemist, physicist or metallurgist, as the case may be. He manipulates his apparatus personally, is in touch with the progress of pure science, and bridges the gap between science and its application. If he goes into the works he has to deal with the common materials of construction, and to direct manual labour; he is then an engineer—chemical, metallurgical, civil, mechanical or electrical—for the special function of an engineer is to direct natural forces to the service of man.

After the war, the nations will be faced with the task of the replenishment of an impoverished earth. Those peoples who can effectively bring into close relationship science and the practical man will succeed in the industrial struggle which is sure to come.

In an after-dinner speech the president (Mr. W. J. Jones) referred to the enormous extension of home supplies of refractory materials since the commencement of the war, and mentioned that the present average output of refractories for munition purposes alone represents 200,000 tons per month, or at the rate of 720,000,000 bricks per annum. In the case of silica bricks the output had been increased from 7,500,000 to between 11,000,000 and 12,000,000 per month, and for many months there has been no shortage anywhere. As regards magnesite bricks for lining basic steel furnaces the present position was also pronounced to be safe, with larger stocks of magnesite bricks and raw material than ever before, in spite of a great increase in the demand. The quality, too, of magnesite bricks is continually improving. The present output averages 500,000 per month, and there is no likelihood of British industries ever again being dependent on supplies from enemy sources.

The president uttered a warning as regards methods of manufacture, pointing out that improvements will have to be made if our manufacturers desire to maintain their place in the industry under normal competitive conditions. This applies to the exercise of more care in selecting the materials, in washing to remove foreign matter, in the grinding, addition of bond, mixing (often uneven), texture of bricks (too varied), moulding, setting and burning.

At the business meeting held on Wednesday morning it was announced that the next meeting of the Refractory Materials Section would be held at Swansea in the autumn, and the following meeting at Middlesbrough in the spring of 1919. It was also mentioned that the council had fixed the subscription for 1918 at 25*s.* for ordinary members and 2 guineas for firms.

It may be added that Wednesday afternoon was taken up with visits by three separate parties to the works of Messrs. Vickers, Limited, John Brown and Co., Limited, and Steel, Peech and Tozer, Limited. These visits were largely attended and proved to be exceedingly interesting.

THE STABILITY OF AEROPLANES.

TO THE EDITOR OF ENGINEERING.

SIR,—Our attention has been fixed by an article "Stability of Aeroplanes" by Mr. H. A. Webb, in your issue of May 3, wherein the author seeks to overcome the mathematical difficulties of moving axes of reference by referring the motion of the aeroplane to fixed axes. One cannot help feeling that the student who would be overcome by the mathematical difficulties of moving axes would quite willingly accept the final stability equation without qualms, whereas the more inquiring mind which demanded an understanding of how these were arrived at would certainly not be satisfied with Mr. Webb's demonstration. Most students of stability have carried through the investigation from the point of view of final axes as far as possible, but the troubles do not exist where Mr. Webb imagines them. Essentially these lie in the fact that the moments of inertia, &c., of the machine are changing with reference to axes fixed in space, a fact to which Mr. Webb makes not even a passing reference. That the dynamics is thoroughly unsound is evident from equations (6) and (7), from which it appears that the equations of motion with reference to fixed axes are identical with those for moving axes! This is in itself the "reductio ad absurdum."

Yours faithfully,
W. L. COWLEY,
H. LEVY.

The National Physical Laboratory, Teddington, Middlesex, May 10, 1918.

[We forwarded a proof of this letter to Mr. H. A. Webb, who has sent us the following reply.—ED. E.]

TO THE EDITOR OF ENGINEERING.

SIR,—Thanks for your courtesy in sending me a copy of a letter from Mr. W. L. Cowley and Mr. H. Levy, dated May 10, criticising my article "Stability of Aeroplanes," in your issue of May 3; and for giving me the opportunity of reply. I will deal in reverse order with the points raised.

My critics state: "that the dynamics is thoroughly unsound is evident from equations (6) and (7), from which it appears that the equations of motion with reference to fixed axes are identical with those for moving axes! This is in itself a *reductio ad absurdum*." On the contrary, it is perfectly true!

The identity of the equations may be seen by mathematical readers who will differentiate equation (3) page 143, Bairstow, *loc. cit.** They will find that, in Bairstow's notation, to the order of small quantities considered, not only do

$$p = \dot{\phi},\ q = \dot{\theta},\ r = \dot{\psi},$$

but also

$$\dot{p} = \ddot{\phi},\ \dot{q} = \ddot{\theta},\ \dot{r} = \ddot{\psi},$$

ϕ, θ and ψ being referred to fixed axes; and p, q and r to moving axes. So much for the *reductio ad absurdum*. Further, I think this is not a fluke, but a particular case of the following general theorem, which I believe to be true, and of some physical interest. When a rigid body, moving in a straight line with uniform velocity and *without rotation*, under any forces, is slightly disturbed, the approximate equations of disturbed motion will be the same, whether axes fixed in the body, with the origin at the centre of gravity, are used, or axes fixed in space; provided that, in the steady motion, these sets of axes are parallel to each other, *and also parallel to, or coincident with, the principal axes of inertia of the body.*

To come to the next point. My critics state that "essentially the troubles lie in the fact that the moments of inertia, &c., of the machine are changing with reference to axes fixed in space, a fact to which Mr. Webb does not even make a passing reference." I made no reference to this fact because no troubles arise from it, to the order of small quantities considered, provided that in steady motion (*a*) there is no rotation and (*b*) the fixed axes used are parallel to the principal axes of the body; on both of which points I inserted a warning (§§2 and 5). I invite my critics to exercise their physical insight by trying to discover why such troubles vanish under the conditions (*a*) and (*b*).

Finally, not 10 per cent. of technical students (for whom primarily, as stated in §1, the article was written) are reasonably conversant with moving axes methods. This statement may surprise my critics, but I make it after ten years' experience of teaching. If they doubt it, perhaps they will make inquiries among professors of engineering. Now then, let me grant for the moment, just for the sake of argument, that my proof is as shaky as my critics think, and that its only merits are that it is simple and plausible and gets the answer right. Well, I maintain that the student would rather have a slipshod proof than none at all, and I will prove this by taking a parallel case. The ordinary theory of bending, when shear is present, is based on a loose physical argument (that plane sections remain plane) far less defensible than my stability proof. The correct mathematical theory of bending, due to St. Venant, has been known for half a century; yet the ordinary proof is in all the text-books. My critics "cannot help feeling" that about ninety per cent. of students, finding St. Venant's proof too hard for them, would despise the text-book proof and prefer to accept their bending formula without any proof at all. On the contrary, they all learn the text-book proof. What have my critics to say to that?

To sum up: I have the highest admiration for the genius of Bryan, who first found the equations of stability; the pioneer chooses his own methods. But now a proof is wanted that emphasises the points of physical importance, and not the points of mathematical importance; and that is so simple that the technical reader can visualise each step physically, and see *a priori* that it is probably true. I claim to have supplied that proof.

Yours faithfully,
H. A. WEBB.

Southcote, Blackwater, Hants, May 14, 1918.

* Technical Report of the Advisory Committee for Aeronautics, 1912–13.

THE DEFINITION OF HARDNESS.

TO THE EDITOR OF ENGINEERING.

SIR,—Permit me a small space in your journal relative to Professor Unwin's article on "The Definition of Hardness," in its current issue.

Whatever may be submitted as a definition of hardness, the methods of determining it are purely arbitrary and relative. While holding this opinion, I might mention that I am not a mineralogist!

In Brinnell's method the figures 3,000 kg. for the load and 10 mm. for the radius of the ball are purely arbitrary. I have never been given a satisfactory reason for these figures. Further, the indentation varies with the load, using the same ball. The very formula given by Brinnell is mathematically erroneous.

If P = Load applied,
h = depth of indentation,
A = area of indentation,
Then H = P/A. (Martell's deduction.)

The method of Shore by his scleroscope is also arbitrary and relative; as is the "autopunch" method of Mr. Heathcoate.

So far as my experience carries me, no method has yet been brought before my notice that can be termed anything but "arbitrary and relative."

Of all the common methods of determination of hardness the Shore scleroscope method, although relative in its results, is quite obvious in its working.

Yours faithfully,
JOSEPH SHIBKO.

39, Newton-road, Sparkhill, Birmingham,
May 18, 1918.

THE ANALYSIS OF ALUMINIUM ALLOYS.—Rapid analyses of aluminium alloys are now much in demand. Reading a paper on the subject before the Nottingham Section of the Society of Chemical Industry (see Journal of the Society, April 15, page 91, T.) Messrs. B. Collitt and W. Regan stated that they agreed in the whole with the recommendations made last year by Mr. J. H. Stanshie, namely: (1) to open out the alloys with a solution of caustic soda, (2) that in that case practically all the zinc and aluminium would be in the filtrate, while copper, iron, nickel, or magnesium and all the manganese (except a trace) would be found on the filter; (3) that a small amount of aluminium would also remain on the filter, so that the iron could not be precipitated by ammonia. They distinguished, for analytical purposes, alloys containing between 10 per cent. and 15 per of copper (with or without manganese, 1 per cent.); alloys containing 10 per cent. and 20 per cent. of zinc, up to 5 per cent. of copper, and small amounts of one or more other metals (Fe, Ni, Mn, Mg): alloys with up to 5 per cent. of copper and amounts up to 2.5 per cent. of the other metals, including zinc; lead and tin were absent in the alloys they had dealt with. They did not make use of gravimetric (density determination), magnetic and electrolytic methods (though the latter would be convenient for zinc); iron they estimated volumetrically with the aid of stannous chloride; silicon was always tested for, but a convenient direct method for determining aluminium does not exist yet.

TABLES OF DECIMAL COINAGE, METRIC AND BRITISH WEIGHTS AND MEASURES.—Messrs. Eyre and Spottiswoode, Limited, have issued a series of tables, prepared by Mr. A. J. Lawson, M.Inst.C.E., and printed in English and Italian, for the purpose of facilitating trade between ourselves and our transalpine ally. Hitherto Italy has imported chiefly from Germany on account of the proximity of the two countries, but it is hoped that in the future there may be more trade with England. To attain this end it is desirable that the units of measurement should be better understood by both buyers and sellers. The volume includes Price Conversion Tables, depreciation tables, metric weights and measures and British equivalents beginning at a milligramme and a millimetre, and covering both linear, square and cubic measures. British equivalents are also given of all dimensions from 0·01 mm. up to 25·03 mm., advancing by $\frac{1}{100}$ mm. Then come equivalents from $\frac{1}{4}$ mm. to 127 mm., advancing by half millimetres. Next follow several pages of multipliers for the conversion of Metric and British Weights and Measures, worked out to 10 places of decimals. The miscellaneous tables include the specific gravity of metals, timber and stone, &c., pressure and stress, area and circumference of circles, international metric standard screw threads, American standard screw threads, British standard Whitworth screw threads, dimensions of test pieces, units of heat and work, dimensions of the earth, the force of gravity at different places in metres per second, velocity of falling bodies from different heights, resistance of trains on the level, resistance due to gradient, safe speed on curves. The remainder of the book deals with setting out railway curves and calculating earthwork. The volume should be very useful to all engineers, but particularly to those who have to prepare designs and estimates in metric measures. The price is 5s.

GERMAN LIGNITE-ELECTRIC GENERATING STATION.

WE read in the *Revue Générale de l'Electricité*, Paris that the Allgemeine Elektricitäts Gesellschaft put down before the war, at Bitterfeld, close to important lignite deposits, a large electric generating station, the power of which was to reach 140,000 h.p. The current was to be transmitted to Berlin. When the war so unexpectedly broke out, says *Elektroindustrie*, Zurich, from which journal our Paris contemporary has taken the present information, this generating station was found a most useful enterprise; the State purchased the current and utilised it in large electrochemical works which were rapidly put down. It was stated that the A.E.G. sold the current at the rate of 0·9 pfennig (0·108*d.*) per kilowatt-hour; the statement was also made that power stations which utilised lignite could generate current as cheaply as the Swiss hydro-electric plants. It was found later, however, that for the concern to pay, the current should be sold at 1·5 pfennig (0·18*d.*) per kilowatt-hour at the switchboard; and although the State works later increased the price they paid for current, the A.E.G. were the losers.

Owing to the heavy outlay incurred by the construction of this generating station, the A.E.G. company was obliged last spring to increase its capital, and the director, Mr. Rathenau, had to confess at the general meeting that the hopes which had been placed upon a power station, utilising lignite as fuel, did not all come true, adding that the experience gained at Bitterfeld showed that for the electrochemical industry the required current should be obtained from hydro-electric power stations.

The author of the article in the Swiss journal was able to ascertain that notwithstanding the improved mechanical appliances used for extracting the lignite, a large amount of labour was necessary. The removal, first, of a layer of earth about 12 ft. in thickness appeared to him to be a particularly costly undertaking. At present, war prisoners were mostly at work, but when in normal times these men are replaced by ordinary labour, the getting of the lignite and its carriage to the station will be very costly. The maintenance of the large boilers also leads to a heavy outlay. It is doubtful whether the current can be obtained at a price below 1 pfennig (0·12*d.*) per kilowatt-hour.

Since the Bitterfeld plant of the A.E.G. sold to the State the greater part of the current generated (a total of 300,000,000 kw.-hours last year), it was to be expected that the State should finally purchase the plant. The purchase was completed recently. The price of the station was about 28,000,000 marks, that of the land and lignite deposits 6,000,000 marks, whilst that of the mining installations was also about 6,000,000 marks. The State now works the station in the form of a company with share capital.

PERSONAL.—The Premier Cooler and Engineering Company, Limited, of Broadway-court, Broadway, Westminster, are removing on the 26th inst. to Station Works, Shalford, near Guildford, Surrey, to which all communications should be addressed. Their telegraphic address will be "Preecooler, Shalford," and their telephone number "27 Shalford."

EDGE EFFECT IN COPPER BUS-BARS.—In collaboration with the General Electric Company, the Electrical Engineering Department of the Massachusetts Institute of Technology has been conducting measurements on the increase in the resistance of copper bars—such as used behind the low-tension switchboards of central stations supplying light and power—which these bars undergo when they carry alternating currents of frequences up to 60 cycles per second instead of continuous currents. The bars were supplied in lengths of 6 m. of a cross-section of 102 mm. by 6·35 mm. (4 in. by $\frac{1}{4}$ in. = 1 sq. in.), and the experiments were made on rectangular loops, formed by joining the bars with the aid of non-magnetic metallic clamps. The distance between the going and returning sides of the loop, 17·8 m. in length, was first kept at 60 cm. At 20 deg. C. the 36 m. of bar and of connection had a resistance of 955 microhms, and this very low resistance caused difficulty in the measurements. It took months before three different methods applied gave concordant results with alternating currents ranging from 100 amperes up to 350 amperes. The final results were: With 60·8 cycles at 29 deg. C. the resistance ratio was $R^1/R = 1·3$, with 24 cycles at the same temperature it was 1·1. That is to say, the resistance of the alternating currents R^1 was, at 60 cycles, about 30 per cent. higher than with continuous currents R, and at 24 cycles 10 per cent. higher. This increase was largely due to the edge effect and not to the ordinary skin effect; the edge effect is, of course, only a particular aspect of the skin effect. Alternating currents are crowded near the surface and edges, but at the higher frequency of 60 cycles the skin effect would only account for a resistance rise of 13 per cent.; that increase would have been observed if the bars of 1 sq. in. section had been replaced by circular copper rods at 25 deg. C.; but such rods would heat up much more with the current owing to the smaller surface. Tubular conductors would avoid this heating; but tubes would be very awkward parts of switchboards. In the further experiments with shorter rectangles higher resistance increases were observed; with loops 4·9 m. long, the sides 5 cm. apart, the ratio was 2·2 at 61 cycles and 27 deg. C. The sides of this loop were composed of three bars in parallel, 6·35 mm. apart, giving an aggregate conductor of 102 mm. by 31·8 mm.; with the three parallel bars 63·5 cm. apart, the ratio decreased to 2·0. In these latter experiments the current intensity was raised to 1,000 amperes.

12-SPINDLE IGNITION-TUBE MULTIPLE DRILLING MACHINE.

CONSTRUCTED BY THE LANGELIER MANUFACTURING COMPANY, ARLINGTON, CRANSTON, R.I., U.S.A.

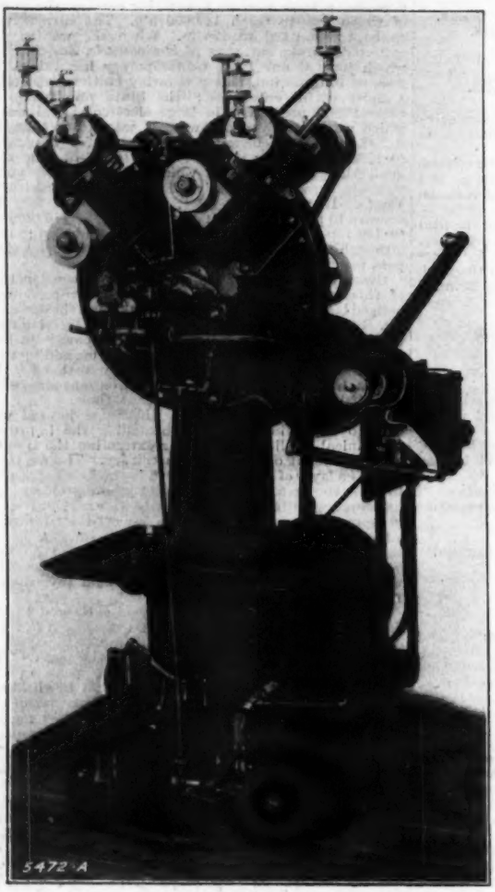


FIG. 1.

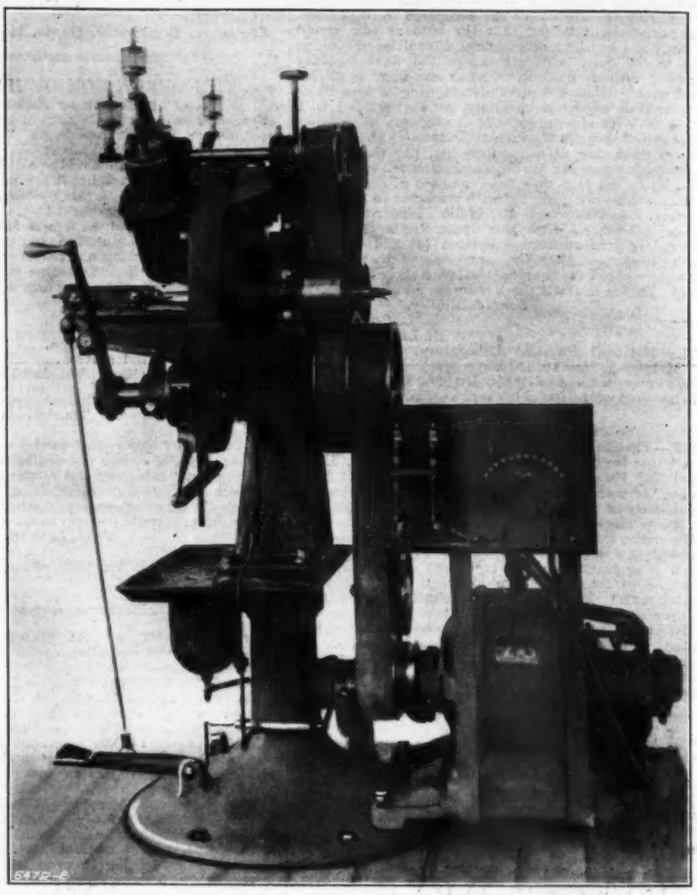
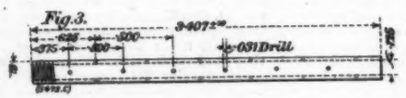


FIG. 2.

THE machine illustrated on this page by Figs. 1 and 2 was designed specially for drilling in one operation the 24 holes, 0·031 in. in diameter, in the wall of the Primer ignition tube shown in Fig. 3. The machine is hand and foot operated.

The drilling is done by two six-spindle multiple-drill heads located 90 deg. apart on the upper half of a vertical faceplate. The spindles in one head are offset to a position midway between those in the other head. Each head drills diametrically through both walls of the tube. The drills are held in small taper-threaded collets in the chuck end of the drilling spindles. The drilling heads have full ball bearings and are driven by an endless woven canvas belt at the back of the machine. A screw belt tightener is used to obtain the proper driving-belt tension. The feed for the drilling heads is operated by a long hand lever mounted on a sleeve pinion which meshes through an intermediate gear to a ring gear located concentrically in the vertical faceplate to which the drilling heads are attached. The ring gear is mounted on ball bearings so as to make the feel of the hand lever as sensitive as possible. The ring gear is connected to the drill-head feed sleeve by means of double pinions, the pinion for the feed sleeve having friction clutches so that it is possible to locate each head individually to its proper drilling position; this also facilitates the putting in and taking out of drills. The feed lever has a spring return. The drilling spindles run at 4,800 r.p.m. Special means are provided for insuring generous lubrication to all high-moving parts. An unskilled operator can drill seven tubes per minute. A cutting fluid similar to cut-rite is used, and is supplied by a rotary pump. The tube to be drilled is held and located in its drilling position by means of a self-opening and closing jig. The jig is mounted upon a slide, the friction of the slide being sufficient to carry the tube from the loading position to the drilling position and *vice versa*. The slide is operated by a foot lever, the depressing of which moves the slide to the loading or

Fig.3.



out position, and also automatically opens the jig and releases the tube. When the drill tube is taken out and a blank one put in, the foot lever is released. The releasing of the foot lever first causes the jig to close and then moves it to the drilling position at the intersection of the drilling heads. The tube is held at the ends by means of 45-deg. cups. The jig has drill-guide bushings, and an open top which permits the quick loading and unloading of the jig; also a free access of the cutting fluid to the drills. A thumb-spring lever is used automatically for lifting the front end of the tube out of the jig, so that the operator can easily take hold of it. The machine is driven by a 3-h.p. Westinghouse electric motor mounted in the base. A ball-bearing belt-tightening pulley is used for the motor belt. The machine occupies a floor space of 32 in. wide by 62 in. deep, and stands 60 in. high. It is constructed by the Langelier Manufacturing Company, of Arlington, Cranston, R.I.

HIGH-SPEED INTERNAL COMBUSTION ENGINES.*

By HARRY R. RICARDO, B.A., Associate Member.

IN the following paper the author proposes to examine and set out some of the features of high-speed engine design, and to indicate some of the points upon which the designers of these engines have concentrated their attention. In the first place, most of these smaller high-speed engines are designed to run on petrol, and it is sometimes argued that the conditions under which they operate are totally different from those that apply to the larger and heavier types of internal-combustion engines. This is true, but to a limited extent only, for, generally speaking, what applies to a petrol engine will, with certain reservations, apply equally to a gas or Diesel engine, while, so far as mechanical considerations are concerned, the problems to be faced are practically identical in either case.

The design of internal combustion engines in this country has during the last twenty years proceeded along two widely different lines, directed by two separate schools. On the one hand we have the designers of what may be termed the slow-speed type of engine who have consistently had to compete with, and have based their designs upon, steam-engine practice, and on the other hand we have the designers of small high-speed engines who have appeared with the advent of the motor car. The latter have created a school of thought of their own, and have developed along lines which are distinctly enterprising. Between these two separate schools, prior to the outbreak of war, there had been practically no interchange of ideas or experience. Each was as ignorant of what the other was doing or aiming at as though they had been working at totally different problems. If we review the progress of both schools impartially, we find that the slow-speed school has consistently designed their engines upon sound thermo-dynamic lines, and has been influenced very largely by such able and distinguished men as Sir Dugald Clerk, Professor Hopkinson and many others. They have, however, exhibited a decided lack of enterprise or initiative in dealing with the mechanical features. On the other hand, we find that until quite recently, at all events, the designers of the high-speed school have shown an utter indifference to the laws of thermo-dynamics, their ignorance of which has been, for the most part, profound, but they have shown a creditable degree of enterprise and imagination when dealing with the mechanical problems. It is surprising that in spite of the fact that their knowledge of the thermodynamic laws might in most cases be summed up as consisting of a mass of vague superstitions, they have nevertheless succeeded, through a laborious process of trial and error, in producing engines whose efficiency is quite comparable with those of the low-speed school. As an illustration of the complete lack of intercommunication between the two schools, the author would cite as one

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders at Newcastle-upon-Tyne, on April 30.

example the case of the 40 h.p. Mércedes car. This car when it first appeared produced something of a sensation because its engine was really reasonably silent, at least by comparison with other engines of that date. On careful investigation, it was found that it embodied an astounding and novel feature, namely, mechanically-operated inlet valves; and yet such valves had been used as a matter of course on nearly every gas engine for at least thirty years. Again, it was not until quite recently, in fact since the outbreak of war, that the designer of the heavier slow-speed type of engine really began to awake to the vital importance of cutting down the weight of the reciprocating and rotating parts, although light moving parts have for years formed the very essence of high-speed engine design.

During the course of the war the development of light high-speed engines has progressed with remarkable rapidity, and has received a very great impetus from the fact that a large number of well trained and scientific men have devoted their attention to it, and taking advantage of the many excellent mechanical features already to be found in these designs, have also directed their development along sound scientific lines.

In answer to any imputation as to their lack of theoretical knowledge, the designers of high-speed petrol engines almost invariably used to reply with the retort that, besides being able to run at much higher piston speeds, their engines could use higher mean pressures, and showed a thermal efficiency equal to, and, in some cases, relatively higher than, the average gas engine. This retort was generally true, and the author proposes, before proceeding further, to devote a short time to comparing the advantages and disadvantages of, say, town gas and petrol as a fuel. In the first instance, other things being equal, the power output of any internal-combustion engine depends upon the weight of oxygen that can be taken into the cylinder and burnt in unit time. Here petrol scores a very decided advantage for three reasons:—

1. In order to consume the whole of the oxygen present in the cylinder, the volume of petrol vapour required is only slightly over 2 per cent., while that of town gas is nearly 17 per cent., consequently the volume of oxygen dealt with in the case of petrol is about 15 per cent. greater.

2. Owing to the latent heat of evaporation of petrol the temperature of the working fluid is reduced both before and during its entry to the cylinder. Hence a slightly greater weight is taken in for a given volume.

3. After combustion the specific volume of the working fluid consisting of an air-petrol mixture is increased by about 4 per cent. to 5 per cent., while that of an air-gas mixture is reduced by about 3 per cent.

On these three grounds alone petrol scores heavily, for not only does the fuel itself displace less oxygen, but it also withdraws heat from the charge, and thereby increases its weight, while finally the actual volume of the charge after combustion is greater than before. On the other hand, petrol labours under two serious disadvantages:—

1. Owing to its very limited range of inflammability it is not possible, as with town gas, to work with a weak mixture. In fact, the mixture giving complete combustion is almost identical with that giving maximum economy, for if the mixture be weakened to any appreciable extent below that required to give complete combustion, inflammation is seriously delayed, and continues throughout the expansion stroke. As a result of this peculiarity, it is not possible by ordinary means to reduce the flame temperature, and since the efficiency of any engine, relative to the air cycle efficiency, is dependent upon flame temperature (owing both to direct loss of heat and to the change in specific heat at high temperature) it follows that from this point of view a petrol engine can only operate under the most disadvantageous conditions. (This point is dealt with at greater length in Appendix I.)

2. Owing to its low ignition temperature and to the high proportion of hydrogen present in the fuel, it is not possible to work with so high a compression pressure. In practice the limiting compression ratio that can be used for petrol is about 5 : 1 (depending, of course, upon a number of subsidiary conditions). This gives an air-cycle efficiency of 47·5 per cent. With town gas, on the other hand, it is possible to use a compression ratio as high as 6·25 : 1, giving an air-cycle efficiency of 52 per cent.

These last two conditions operate in favour of gas more particularly as regards fuel efficiency.

Fig. 1 shows two charts giving the limiting efficiencies and mean pressures for: (a) A petrol engine having a compression ratio of 5 : 1; (b) a gas engine having a compression ratio of 6·25 : 1.

The charts show:—

1. The air-cycle efficiency corresponding to the compression ratio.

2. The possible indicated thermal efficiency after deducting the direct heat loss to the walls during the expansion stroke only, and also the inevitable loss due to increase of specific heat at high temperatures. Both these are, of course, dependent upon the flame temperature which again depends upon the mixture density.

3. The highest possible mean effective pressure assuming that the cylinder is completely filled with working fluid at atmospheric pressure at the commencement of the compression stroke, and at a temperature calculated after taking into account the presence of highly heated exhaust products in the combustion chamber and the acquisition of heat during the passage of the working fluid through the inlet valves. (See Appendix II.—Volumetric Efficiency.)

In the case of the efficiency curve for petrol, a second dotted line is shown. This line indicates the thermal efficiency based on that portion of the fuel which is actually burnt. When working with a rich mixture of air and petrol it is possible slightly to increase the mean pressure, though, of course, at the cost of excessive fuel consumption. This is to be accounted for by the fact that: (a) With rich mixtures the flame temperature is slightly reduced, hence the relative efficiency, based on that portion of the fuel only which is completely combined, is slightly increased; (b) the specific volume after combustion may be increased to nearly 10 per cent. as

Fig.1.

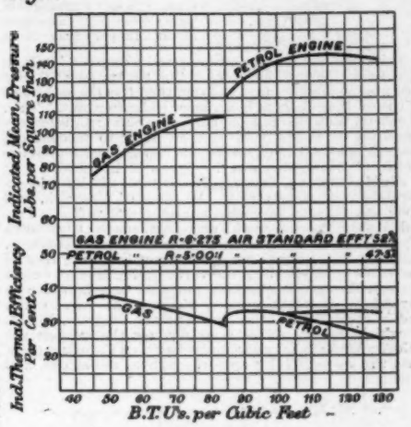
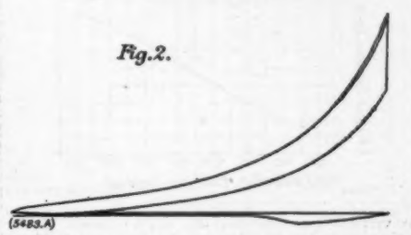

Indicated Mean Pressure Lbs per Square Inch
PETROL ENGINE
GAS ENGINE
GAS ENGINE R=6·275 AIR STANDARD EFFY 52%
PETROL " R=5·00 " " " 42·5%
Ind. Thermal Efficiency Per Cent.
GAS
PETROL
B.T.Us. per Cubic Foot

Fig.2.



against the 4 per cent. or 5 per cent. in the case of a normal mixture. This increase in the apparent efficiency though obtained at great cost of fuel does result in a slight increase in the mean pressure in the case of petrol, but does not do so in the case of gas.

We will consider next the case of the Diesel engine. This engine has the following advantages in its favour:—

1. No fuel is taken into the cylinder until after the end of compression, hence no oxygen is displaced and the greatest possible volume is taken in.

2. The combustion of crude oil and air also results in an increase in the specific volume as in the case of petrol.

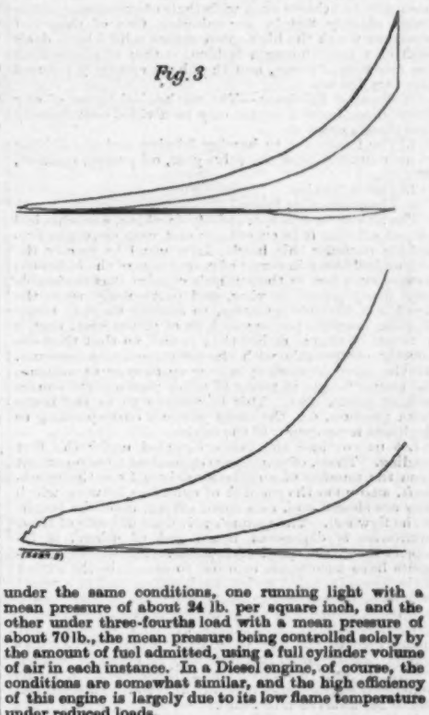
3. Additional air, compressed separately, is nearly always admitted to the cylinder along with the fuel. The increase in mean pressure due to the presence of this additional air is invariably credited to the indicated power of the engine. This gives the Diesel engine an apparent indicated power which is altogether illusive. In common justice, the indicated horse-power absorbed by the compressor should be deducted from that developed in the cylinder, before any comparison is made between it and other internal-combustion engines.

There are so many variables connected with the Diesel cycle that the author has not attempted to show a comparative mean pressure and efficiency curve. In the first place the air-cycle efficiency itself varies with the flame temperature. Again, the proportion of air admitted along with the fuel has a powerful influence both on the mean pressure and efficiency and that proportion is a variable quantity. Thirdly, the highest mean pressure attainable is governed not so much by consideration as to the quantity of oxygen present in the cylinder, but rather by the quantity that can be brought in contact with the particles of fuel and burnt in the short time available.

From the above figures it is clear that while with petrol it is possible to obtain an indicated mean pressure of 146 lb. per square inch under extreme conditions, or 136 lb. per square inch under economical conditions; with town gas it is not possible to obtain a higher mean pressure than about 110 lb. per square inch, even when working with the richest possible mixture. On the other hand, with petrol it is not possible under any normal circumstances to obtain an indicated thermal efficiency of more than 33 per cent., with town gas it is possible to obtain as high an efficiency as 37·5 per cent. when working with a weak mixture and a low flame temperature. The best modern petrol engines, such as those employed for aircraft work, do actually realise an indicated thermal efficiency of over 32 per cent. while gas engines have occasionally shown as high an efficiency as 37 per cent., showing that in both cases there is not much scope for improvement so long as the usual cycle is adhered to. It is obvious, however, that the thermal efficiency of either type of engine, and more particularly of the petrol engine, could be greatly increased by working with a lower flame temperature; theoretically, the efficiency rises as the flame temperature is reduced until at the point of no heat supply the efficiency will be equal to the air-cycle, but the power will be nil.

While the author has stated that owing to the very limited range of inflammability of petrol and air mixtures it is not possible by ordinary means to work with a weak mixture and hence at a lower flame temperature, this, of course, applies only so long as the working fluid is homogeneous. It is interesting to consider what would happen if into a cylinder full of air there were inserted a paper bag containing a small charge of air-petrol mixture of normal density, and that at the end of the compression stroke this mixture were ignited and the bag burst so that its contents, already fully aflame, were discharged into the large excess of air present. Under these circumstances the effect would be equivalent to working with an extremely weak mixture, the mean flame temperature would be very low and the efficiency very high. Some such condition as this can be reproduced in a practical form by means of stratification, and the indicator diagram, Fig. 2, taken by means of an optical indicator from one of the author's high-speed experimental engines shows the results obtained. When running under these conditions the indicated thermal efficiency was no less than 38 per cent., with a mean pressure of 23 lb. per square inch. Fig. 3 shows two diagrams taken consecutively from the same engine

Fig.3



under the same conditions, one running light with a mean pressure of about 24 lb. per square inch, and the other under three-fourths load with a mean pressure of about 70 lb., the mean pressure being controlled solely by the amount of fuel admitted, using a full cylinder volume of air in each instance. In a Diesel engine, of course, the conditions are somewhat similar, and the high efficiency of this engine is largely due to its low flame temperature under reduced loads.

While comparing the two fuels, gas and petrol, there are two other points which need consideration. Petrol is a liquid, and before it can be used in the engine it must be vaporised, or at least finely pulverised. This entails a certain loss, though a very small one, and it also imposes certain restrictions in the design, especially in the design of the pipework which must be carried out in such a manner that the pulverised and partially vaporised particles of petrol are kept in rapid and, as far as possible, continuous motion, in order to prevent them from precipitating on the walls of the pipework. The other peculiarity of petrol is its readiness to detonate on account of its chemical instability and of the large proportion of hydrogen present. Such detonation is generally referred to as "pinking," and often, but quite erroneously, as pre-ignition. Pre-ignition means, of course, self-ignition of the fuel before the end of the compression stroke. Detonation, on the other hand, is merely extremely rapid burning, so rapid indeed as to cause local rises of pressure which spring the walls of the cylinder and cause them to vibrate as though they had been struck by a hammer. What actually occurs appears to be this: A portion of the working fluid in the neighbourhood of the sparking plugs is ignited and proceeds to burn in the usual manner, but so rapidly that it compresses before it the rest of the unburnt charge, until the heat of compression is such that the unburnt residue ignites spontaneously and suddenly throughout its whole bulk; in other words, flame propagation proceeds normally at first and then suddenly changes and becomes practically instantaneous. This tendency to detonate is very tiresome and it, of course, increases as the compression ratio is increased and the temperature and pressure of the working fluid are raised by compression. (See Appendix III.) It is, as might be expected, dependent to a considerable extent upon the shape of the combustion chamber and the position of the igniter, and it also depends upon the density of the fuel; the denser the petrol the greater the tendency to detonate, presumably because the heavier fractions are chemically less stable than the lighter ones. It becomes particularly troublesome when working with

paraffin. Such detonation can be kept in check in several ways :—

1. By reducing the temperature and pressure of compression by the admission of water or other such means.

2. By increasing the proportion of carbon in the fuel by mixing it with hydrocarbons of the aromatic series, such as solvent naphtha, metaxylene, or benzol.

3. By introducing inert gases, and preferably by adding gases containing carbon such as carbon dioxide ; in practice this can be accomplished by readmitting cooled exhaust gases, a method frequently adopted in the case of large gas engines using coke-oven gas, in which the proportion of hydrogen is large, and the same trouble arises.

This tendency to detonate compels the use of a lower compression ratio than would otherwise be necessary and is a serious handicap to the petrol engine.

In modern high-speed engines every effort is made to obtain the highest possible mechanical and volumetric efficiencies, and these efforts have met with such success that the author can point to examples of quite small engines running at piston speeds as high as 1,800 ft. per minute, in which the mechanical efficiency is over 90 per cent., and the volumetric efficiency over 96 per cent., a result which the low-speed school have seldom, if ever, been able to achieve even with their conventional piston speed of only 800 ft. per minute. One of the chief problems which the high-speed engine school have dealt with in a very thorough fashion, is that of eliminating the mechanical losses, and they have certainly reduced this to a fine art.

Mechanical Efficiency.—The mechanical losses of any internal-combustion engine may be divided conveniently into three groups :—

1. The losses due to bearing friction and the driving of such auxiliaries as the valve gear, oil pumps, ignition, &c.

2. Piston friction.

3. Fluid pumping losses.

The last of these is not, strictly speaking, a mechanical loss at all, but it is customary and very convenient to include it under this head. It is usual to specify the mechanical losses in terms of percentage of the indicated horse-power, but in the author's opinion it is preferable from many points of view, and particularly when the speed is a variable quantity, to classify them in terms of mean pressure per square inch of piston area, that is in terms of torque rather than power, so that they are directly comparable with the effective mean pressure. All the more so since it is now customary to measure the actual torque in terms of mean pressure per square inch of piston area. This is referred to as the brake mean pressure, *i.e.*, the mean pressure corresponding to the brake horse-power of the engine.

Let us consider the losses included under the first heading. These, of course, are dependent to some extent upon the number of auxiliaries driven from the crank-shaft, also upon the number of cylinders between which they are shared and, to a small extent, upon the weight of the flywheel. The torque equivalent of some of these auxiliaries is dependent upon, and of others, is independent of, the speed of rotation. Numerous experiments have been made in order to ascertain the extent of the losses included under this heading, and as a result they have been found to range from 1·5 lb. per square inch mean pressure in the case of a modern six-cylinder or twelve-cylinder aero-engine up to over 3 lb. per square inch in the case of a heavy single-cylinder gas engine. As a general rule they may be taken as ranging from 2 lb. to 2·6 lb. per square inch for an average high-speed engine, and may for a 100-h.p. six-cylinder engine be subdivided as follows :—

	Lb.	Lb.
Bearings		0·75 to 1·00
Valve gear		0·75 to 0·80
Magneto		0·05 to 0·10
Oil pump		0·15 to 0·25
Water pump		0·30 to 0·50
Total		2·00 to 2·65

Piston Friction.—This latter is generally by far the largest item, and is somewhat difficult to account for. In high-speed engines with enclosed crank chambers and forced lubrication the piston may be regarded as being practically oil-borne. Compared with the main bearings, however, the average loading is very much lighter and the rubbing velocity not so very much higher. At first sight, therefore, it would appear that the friction of the piston on the cylinder walls should not be greater than that of an equivalent area of bearing surface in other parts of the engine ; that it is, in fact, enormously greater is probably to be accounted for, in part by the fact that the motion of the piston is reciprocating and not continuous, and in part by the fact that the lubricating oil is always more or less contaminated and carbonised partly by the escape of a very small quantity of burning gases past the piston rings, and partly by the exposure of the cylinder walls to the high temperature of combustion which tends to carbonise the film of the oil adhering to them. As a result of this contamination the viscosity of the oil is increased enormously, and therefore also its resistance to shear. A very large number of experiments have been carried out by the author and others in order to determine both the cause and extent of piston friction in gas and petrol engines. Briefly it seems that the main causes are those stated above, and that the extent is almost directly proportional to the average thrust on the cylinder walls and indirectly proportional to the rubbing velocity and the area of surface. It is found that when the area of surface is equal to π times the diameter—that is when the length and diameter are equal—the piston friction in terms of pounds per square inch can be found from the formula :

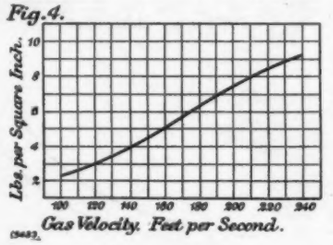
$$\frac{\text{Mean fluid pressure}}{4} + \frac{2 \text{ mean inertia pressure}}{3} \Big/ 10$$

Plus a constant which includes the average pressure on the cylinder walls due to the compression and which depends also to some extent upon the number and strength of piston rings. This constant may vary from 1·5 lb. to 4 lb. per square inch, but generally averages about 2 lb. per square inch.

This formula is, of course, purely empirical. It is open to criticism on the grounds that the rubbing velocity is not taken into account, and that therefore the resistance of the oil film to shear is assumed to be constant. This, of course, is not the case, but the apparent error is largely corrected by taking very prominently into account the average component of thrust due to the inertia pressure which, of course, varies as the square of the speed.

Fluid Pumping Losses.—The extent of these losses depends very largely upon the form of pipework, and upon the velocity through the piping and valves. Provided that the pipework, and particularly the intake pipe, is reasonably short, *i.e.*, not more than 8 diameters, and that the internal diameter is not less than that of the valve port, also that the valve timing is more or less normal, the loss due to fluid pumping may be taken as dependent upon the velocity through the valve ports, and is approximately as shown in the diagram, Fig. 4, in which the horizontal scale denotes the average gas velocity through the valve ports based on the assumption that the valve is fully open throughout the stroke, and

Fig. 4.



the vertical scale denotes the mean pressure of the suction-exhaust loop. This curve has been prepared from a very large number of indicator diagrams and from

Fig. 5.

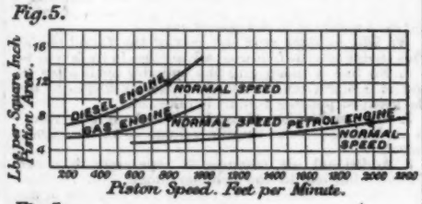
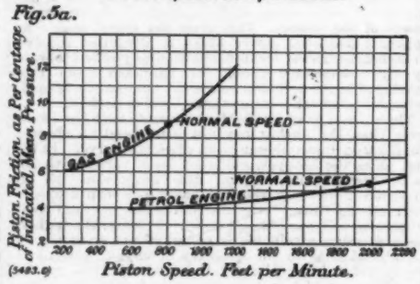


Fig. 5a.



motoring tests, and may be taken as being substantially correct and applicable to any class of four-cycle engine.

In the next table are given the mechanical losses of three actual engines, each of about 80 h.p. per cylinder :—

1. A Diesel engine bore 16·0 in., stroke 19·0 in., normal speed 250 r.p.m. Piston speed 790 ft. per minute. Weight of reciprocating mass, 994 lb. Mean gas velocity through valves, 150 ft. per second.

2. A gas engine bore 15·0 in., stroke 24·0 in., normal speed 200 r.p.m. Piston speed, 800 ft. per minute. Weight of reciprocating mass, 655 lb. Mean gas velocity through valves, 130 ft. per second.

3. A petrol engine bore 7·25 in., stroke 8·5 in., normal speed 1,400 r.p.m. Piston speed, 1,980 ft. per minute. Gas velocity through valves, 130 ft. per second. Weight of reciprocating mass, 11·35 lb.

In the tabulated figures, in order to make them truly comparative, no account is taken of the air compressor usually fitted to Diesel engines. The indicated mean pressure is taken as 89·0 lb. per square inch in the gas engine and 130·0 lb. per square inch in the petrol engine. Figs. 5 and 5 (a) show the loss due to piston friction for these engines.

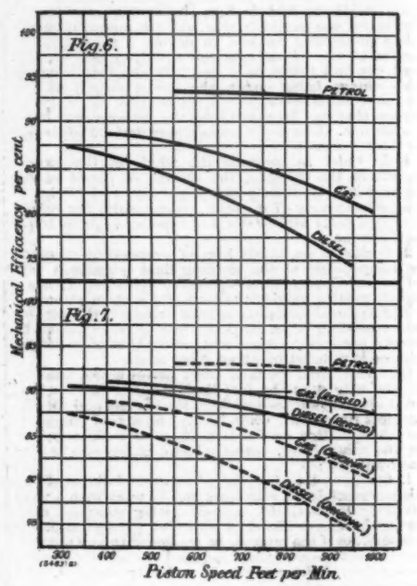
It may be argued that while the mean pressure taken in the case of the petrol engine is very nearly the maximum obtainable, that taken in the case of both the gas and Diesel engine is well below the maximum, and that therefore the comparison is not a just one. The answer to this is that in both the gas and Diesel engines the cylinder bore is so large that it is not possible to work with higher mean pressures owing to the excessive heat

Friction Losses in Terms of Pounds per Square Inch of Piston Area.

	Diesel Engine.	Gas Engine.	Petrol Engine.
	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.
Bearing, &c.	3·5	3·0	1·8
Piston friction	11·8	7·8	7·2
Fluid pumping loss	4·5	3·4	3·4
Total	19·8	14·2	12·4
Brake mean pressure ..	75·0	75·0	118·0
	per cent.	per cent.	per cent.
Mechanical efficiency ..	79·0	84·0	90·6

gradient across the piston and through the walls of the combustion chamber. In the petrol engine, however, with its small cylinder and thin walls it is possible to dispose of the heat, and that with the same, or even a smaller temperature difference between the inside and

Fig. 6.



outside of the cylinder walls and combustion head. Again, in the petrol engine the mean pressure can only be cut down by throttling the charge as already explained, and not by reducing the mixture strength.

In Fig. 6 are shown the curves of mechanical efficiency in terms of piston speed for the three engines. Fig. 7 shows the mechanical efficiency which might be expected from the gas and Diesel engines, assuming that the same attention had been devoted to the design of their pistons and valves, as in the case of the petrol engine.

(*To be continued.*)

THE JURASSIC IRONSTONES.*

The Jurassic Ironstones of the United Kingdom—Economically Considered.

By F. H. HATCH, Past-President of the Institution of Mining and Metallurgy.

(*Concluded from page 562.*)

Treatment of Ore.—So long as the ore was being obtained from the surface, or from under a small cover it was in the oxidised condition (*i.e.*, it consisted of hydrated oxide of iron or limonite), and was fed into the blast furnaces in the raw state. The green carbonate ore now obtained from the mines is, as a rule, calcined at the ironworks before being used. The loss on calcination of Cleveland stone is from 27 per cent. to 30 per cent., carbon dioxide and water being driven off, while the iron is raised to the state of sesquioxide. The ore is then in a more reducible condition and the loss due to the formation of ferrous silicate in the blast furnace is avoided.

On account of the siliceous nature of Cleveland stone, it is necessary, in order to flux it efficiently in the blast furnace, to add a considerable amount of limestone, and about 35,000 tons per week are brought to the furnaces for this purpose from quarries in East Durham, Weardale, Wensleydale and the district south of Darlington.

* Paper read before the Iron and Steel Institute on Thursday, May 2, 1918. Published by permission of the Controller of Iron and Steel Production, Ministry of Munitions.

It is the usual practice to mix the limestone with the raw ironstone and to calcine the mixture in the same kilns.*

The bulk of Cleveland iron is used for steel-making, mainly by the basic open-hearth process. A smaller proportion—about 20 per cent.—is used for foundry purposes.

The alumina-content of Cleveland ironstone makes it difficult to carry sufficient lime in the slag to ensure the production of a basic pig-iron low in silicon and sulphur, and this difficulty is increased by the comparatively high percentage of the latter element in the stone. In order to make a high-class basic pig-iron, a considerable proportion of ores, low in alumina, have to be added to the furnace charge.

Large quantities of pig-iron are, however, made exclusively from Cleveland ores and used for the manufacture of basic open-hearth steel; but in this case the pig-iron is taken to the open-hearth furnace in the molten condition and, before being charged, is desiliconised by a preliminary treatment in a metal mixer.

Chemical Composition.—The average composition of Cleveland ironstone (Main Seam only) has been calculated from works' analyses. As in the case of the Northampton ironstone, the percentages were averaged first for each group and then for the whole, regard being paid to the output of each group.

The following mines are represented:—

Position.	Name of Mines.	Number of Analyses.	Percentage of Iron in Stone as Received.
Mines on outcrop (1st line)	Eston	2	30·2
	Upleatham ..	1	
Mines on outcrop (2nd line)	Park Pit ..	1	28·15
	Skelton ..	1	
	Spawood ..	1	
	Belmont ..	1	
Mines on the dip ..	Loftus	1	28·2
	Brotton ..	1	
	Lumpsey ..	2	
	North Skelton ..	2	
	Kilton	1	
	Lingdale ..	1	
	Stanghow ..	1	
	South Skelton ..	1	
Mines at eastern end of field	Boulby ..	1	25·3
	Grinkle Park ..	1	
Mines at south-west end of field	Roseberry ..	1	25·3
	Ayton	1	

The results are as follow:—

No. of Analyses used in the Calculations.	—	Calculated Average. As Received.	Dry.
21	Fe	28·14	30·15
21	Mn	0·41	0·44
21	SiO_2	11·84	12·70
21	Al_2O_3	10·21	10·95
21	CaO	4·74	5·09
21	MgO	3·54	3·80
21	S	0·26	0·28
21	P	0·47	0·51
21	Moisture	6·80	—
21	Oxygen	9·06	9·72
21	Combined H_2O and CO_2	24·53	26·37
		100·00	100·00

The range of the percentages of the different constituents in the analyses used are as follow:—

	Per Cent.	Per Cent.
Iron	from 33·30 to	24·60
Manganese	„ 0·62 „	0·22
Silica	„ 14·67 „	7·70
Alumina	„ 12·90 „	8·34
Lime	„ 6·34 „	3·74
Magnesia	„ 4·20 „	2·60
Sulphur	„ 0·77 „	0·01
Phosphorus	„ 0·69 „	0·40
Moisture	„ 11·00 „	2·44

As already pointed out on page 515 *ante*, the chief chemical characteristic of the Cleveland ironstones its comparatively high alumina content, which, combined with low lime and fairly high silica, makes it a distinctly siliceous stone, requiring the addition of a considerable proportion of lime to flux it.

The annexed tables give selected complete analyses of Cleveland ironstone as received at the ironworks.

The Lower Lias Ironstone or Frodingham Stone of North Lincolnshire.

Distribution of Workings.—The Frodingham ironstone is worked open-cast along its crop from Thealby in the north to about a mile south of Ashby in the south, a distance of 7 miles; the average width of the belt in which the workings are situated being about 1½ miles. The town of Scunthorpe is situated on the outcrop at about half-way between its most northerly and southern

* I understand from an inquiry kindly instituted for me by Mr. Stephenson, that about five-eighth of the total limestone used is put through the kilns with the ironstone.

No. of Analysis.	Name of Mine.	Owners.	Source of Information.
1	Grinkle Park	Grinkle Park Mining Company	Palmer's Shipbuilding and Iron Company.
2	Roseberry ..	Tees Furnace Company	Cochrane and Co.
3	Boulby ..	Skinningrove Iron Works	Skinningrove Iron Works.
4	„ ..	„ „	„ „
5	Lingdale ..	Pease and Partners	Pease and Partners.
6	Loftus ..	„ „	„ „
7	Belmont ..	Bolckow, Vaughan and Co.	Bolckow, Vaughan and Co.
8	Spawood ..	Sir B. Samuelson and Co.	Sir B. Samuelson and Co.
9	Kilton ..	Dorman, Long and Co.	Bell Brothers.
10	Brotton ..	Morrison and Co. ..	Cochrane and Co.
11	Lumpsey ..	Bell Brothers ..	Bell Brothers.
12	„ ..	„ ..	„
13	Longacres ..	Bolckow, Vaughan and Co.	Cochrane and Co.
14	N. Skelton	„ „	„ „
15	Eston ..	„ „	„ „
16	Skelton ..	Bell Brothers ..	Bell Brothers.
17	Park Pit ..	„ ..	„
18	N. Skelton	Bolckow, Vaughan and Co.	Bolckow, Vaughan and Co.
19	Upleatham	Pease and Partners	Cochrane and Co.
20	Eston ..	Bolckow, Vaughan and Co.	Bolckow, Vaughan and Co.
21	S. Skelton ..	„ „	„ „
22	E. Rosedale (Top Seam)	Lascelles and Shepherd	Lascelles and Shepherd.

—	1. Grinkle Park.	2. Roseberry.	3. Boulby.	4. Stanghow.	5. Lingdale.	6. Loftus.	7. Belmont.	8. Spawood.	9. Kilton.	10. Brotton.	11. Lumpsey.
Fe	24·60	25·43	25·97	26·10	26·12	26·39	26·70	27·00	27·63	27·67	27·79
Mn	0·22	0·44	0·25	0·46	0·29	0·61	0·31	0·39	0·27	0·53	0·43
SiO_2	13·90	12·57	14·04	13·94	14·67	13·84	11·89	12·49	14·63	10·64	13·40
Al_2O_3	11·80	11·17	8·94	11·46	11·58	9·06	9·61	11·99	10·28	10·02	12·90
CaO	4·70	6·07	5·72	5·22	4·58	5·09	5·02	5·50	4·42	4·45	5·33
MgO	2·60	3·17	2·98	3·42	3·49	3·69	3·45	3·31	4·02	3·39	3·43
S	0·25	0·77	0·02	0·42	0·41	0·14	0·06	0·30	0·14	0·29	0·16
P	0·49	0·49	0·41	0·48	0·45	0·45	0·44	0·47	0·43	0·44	0·50
Other constituents	—	—	0·78	—	—	0·78	—	—	—	—	—
Moisture	7·30	8·10	9·00	6·80	6·55	8·20	4·31	6·00	5·00	11·00	5·00
Oxygen	9·22	8·40	8·44	8·41	8·49	8·55	8·33	8·52	8·78	9·00	8·67
Combined H_2O and CO_2	24·92	22·75	22·90	23·05	23·07	22·90	29·38	24·00	23·74	22·72	21·90
Total	100·00	99·36	99·45	99·76	99·70	99·70	99·50	99·97	99·34	100·15	100·00
Fe in sample dried at 212 deg.	26·54	27·68	28·54	27·90	27·96	28·75	27·90	28·72	29·09	30·95	29·25
Character of stone ..	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous

—	12. Lumpsey.	13. Longacres.	14. N. Skelton.	15. Eston.	16. Skelton.	17. Park Pit.	18. N. Skelton.	19. Upleatham.	20. Eston.	21. S. Skelton.	22. E. Rosedale (Top Seam).
Fe	27·92	28·91	29·14	29·35	29·42	29·49	29·57	29·74	31·40	33·30	31·25
Mn	0·33	0·30	0·62	0·35	0·40	0·45	0·34	0·36	0·55	0·41	0·31
SiO_2	13·77	9·04	12·12	8·71	10·48	9·20	11·57	10·10	7·70	9·00	9·00
Al_2O_3	10·39	8·58	10·89	9·90	8·46	8·34	9·65	10·40	9·00	8·75	10·00
CaO	4·39	5·08	3·74	4·56	5·32	4·91	5·19	4·04	4·82	4·60	5·00
MgO	4·10	3·39	3·50	3·15	4·13	4·20	3·71	3·30	3·48	4·00	3·00
S	0·34	0·22	0·31	0·14	0·51	0·58	0·09	0·58	0·05	0·01	0·20
P	0·45	0·40	0·48	0·49	0·50	0·48	0·46	0·49	0·69	0·40	0·92
Moisture	5·00	10·00	6·50	10·70	6·60	7·80	3·99	8·14	7·16	2·44	10·00
Oxygen	8·92	9·62	9·42	9·44	9·45	9·39	9·29	9·79	10·41	10·52	10·77
Combined H_2O and CO_2	24·00	24·14	23·27	23·25	24·33	24·85	25·90	22·36	25·07	26·53	19·53
Total	99·61	99·68	99·99	100·04	99·60	99·62	99·76	99·30	100·33	99·96	99·98
Fe in sample dried at 212 deg. F.	29·39	32·12	31·17	32·87	31·50	31·98	30·80	32·37	33·81	34·13	34·72
Character of stone ..	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous

points. Taking the properties from north to south the following companies are at work:—

Name of Company.	Situation of Quarries.
Frodingham Iron and Steel Co. ...	Thealby.
John Lysaght, Ltd.	Normanby Park.
Yorkshire Iron and Coal Co., Ltd....	E. of Flixborough.
Redbourn Hill Iron and Coal Co., Ltd.	S.E. of Flixborough.
Frodingham Iron and Steel Co. ...	Conesby Farm.
Midland Ironstone Co.	S. of Conesby Farm.
Redbourn Hill Iron and Coal Co. ...	Crosby Warren.
Sheepbridge Coal and Iron Co., Ltd.	Crosby Warren.
Frodingham Iron and Steel Co. ...	Crosby parish.
Walter Scott, Ltd.	Crosby parish.
Lord St. Oswald's Frodingham Ironstone Mines	Near Scunthorpe.
Z. G. Yewdall	Near Scunthorpe.
Trent Iron Co., Ltd.	Near Scunthorpe.
Frodingham Iron and Steel Co. ...	Frodingham parish.
Redbourn Hill Iron and Coal Co., Ltd.	Frodingham parish.
Midland Ironstone Mines	New Brumby.
Lord St. Oswald's Frodingham Ironstone Mines	Brumby.
Frodingham Iron and Steel Co. ...	Ashby South.

Of these companies the Frodingham Iron and Steel Company, John Lysaght, Limited, the Redbourn Hill Iron and Coal Company, and the Trent Iron Company, Limited, send their output to their local furnaces (at Normanby Park, Frodingham, Appleby, &c.), where it is smelted with the more siliceous Inferior Oolite ironstone from the Mid-Lincolnshire Company's mine near Lincoln and from Northamptonshire quarries. The remaining companies send their stone out of the district: Messrs. Walter Scott, Limited, to the Leeds Steel Company; the Sheepbridge Coal and Iron Company, Limited, to their ironworks in Derbyshire; the Midland Ironstone Company to their works at Staveley, near Chesterfield, while the output of Lord St. Oswald's quarries is sold for mixing with more siliceous ironstones, to various ironworks in different parts of the country, among these being the North Lincolnshire Ironstone Company's works at Scunthorpe.

The average weekly output of the producing companies for the last quarter of 1917, and the total for the year, were as follow:—

	Weekly Average	Per Annum (1917).
	Tons.	Tons.
Lord St. Oswald's Frodingham Ironstone Mines ...	18,016	970,760
Frodingham Iron and Steel Company	7,929	412,866
Redbourn Hill Iron and Coal Company, Limited	6,089	233,126
John Lysaght, Limited ...	5,660	304,646
Midland Ironstone Company	5,393	279,489
Yorkshire Iron and Coal Company, Limited ...	2,684	150,652
Sheepbridge Coal and Iron Company, Limited ...	2,574	126,592
Walter Scott, Limited ...	2,385	126,698
Trent Iron Company, Ltd.	1,375	90,548
Z. G. Yewdall	103	4,155
Total	52,208	2,699,532

Method of Working.—At present the Frodingham ironstone bed, which, where undenuded, is 25 ft. to 30 ft. in thickness, but where denuded may be of any lesser thickness, is worked open-cast, the amount of cover removed at present ranging up to 60 ft. Mechanical appliances similar to those already described on page 520 *ante* are used to remove and deposit the overburden on the worked-out areas (see page 520 *ante*). A certain amount of "baring" is also done by hand, the material removed being wheeled on a gantry from the working face to ground from which the ironstone has been removed.

The soil is kept apart, so that on completion of the operations it can be spread evenly over the new surface, with the result that the ground when handed back to the farmer is ready for cultivation.

On account of the great thickness of the ironstone bed, the length of the working faces, the extensive use of mechanical appliances, both for baring and for loading the stone, and the systematised pumping arrangements, the ironstone is won very cheaply. Before the war the cost of the stone in wagons at the quarries probably did not exceed 1*s.* per ton (exclusive of royalty).

The ironstone bed has its full thickness of 25 ft. to 30 ft., when undenuded and covered by Lower Lias clay or shale; when, however, the latter has been eroded the upper portion of the ironstone may be missing, the cover consisting in this case of a later deposit of drift sand (as in Normandy Park). The ironstone bed dips at a very low angle (1 deg. to 2 deg.) to the east, and the surface of the ground is practically level for 1 mile to 2 miles from the outcrop. Since it is proposed to work the bed open-cast under a cover of up to 100 ft. in thickness, a very large quantity of ore, sufficient for

many years' work, is available before mining will be necessary.

Farther east, near Appleby, the ironstone bed has been proved by boring through 300 ft. of the overlying beds, and found to have a thickness of close on 30 ft. It appears probable, therefore, that large reserves of ore will be available for mining when the thickness of the cover prohibits quarrying.

Lithologically,* the Frodingham ironstone is a ferruginous fossiliferous limestone, with distinct oolitic structure. The iron is present as hydrated oxide; but this only applies to the surface rock now being quarried—under a greater cover it will certainly be found as a carbonate. Indeed, this is the case in the lowest beds worked in the quarries.

A small proportion of the upper layers is siliceous. Immediately below the siliceous layers is a seam of dark-coloured shale carrying pyrites. On account of its sulphur-content (about 1½ per cent.) this material is generally eliminated before the ironstone is loaded into wagons.

Below the shale band the ironstone is limey and consists of dark-brown bands rich in iron, alternating with narrow bands of a light-coloured hard shelly limestone, of which the iron-content probably does not exceed 12 per cent. The lowest bed of all is a similar limestone crowded with fossils.

Teall,† who examined some thin sections of the ironstone under the microscope, remarks that the iron is present in the oolitic grains and in pseudomorphs of rolled organic fragments. If the ironstone has originated by the alteration of a limestone the replacement by iron compounds this would appear to have taken place before cementation, since the matrix is not affected and consists of calcite.

Chemical Composition.—The average composition of the Lower Lias ironstone of North Lincolnshire has been calculated from 35 analyses supplied by blast-furnace firms. Properties of the following companies are represented, the number of analyses from each being given in brackets—Redbourn Hill Coal and Iron Company (3), Frodingham Ironstone Mines (15), Walter Scott, Limited (6), Midland Ironstone Company (2), Sheepbridge Coal and Iron Company, Limited (4), John Lysaght, Limited (1), Yorkshire Iron and Coal Company, Limited (1), Frodingham Iron and Steel Company (2), and Trent Iron Company (1).

The method of calculation is the same as described on page 515 *ante*. The results are as follow:—

No. of Analyses Used in the Calculations.	—	Calculated Average. As Received.	Dry.
35	Fe	22·66	25·40
28	Mn	0·96	1·07
34	SiO_2	8·10	9·06
19	Al_2O_3	5·07	5·67
34	CaO	18·15	20·30
11	MgO	1·00	1·12
27	S	0·16	0·18
31	P	0·31	0·35
34	Moisture	10·73	—
	Combined water, CO_2 and O by difference	32·86	36·85
		100·00	100·00

The range of the percentages of the different constituents in the analyses used are as follows:—

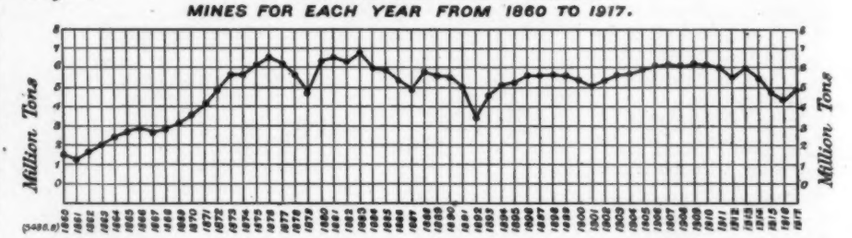
	Per Cent.	Per Cent.
Iron	from 32.19 to	17.69
Manganese	from 1.40 to	0.42
Silica	from 17.94 to	3.66
Alumina	from 10.24 to	2.10
Lime	from 28.00 to	7.48
Magnesia	from 1.67 to	0.18
Sulphur	from 0.42 to	0.05
Phosphorus	from 0.45 to	0.20
Moisture	from 16.00 to	5.30

The following are selected complete analyses of Lower Lias ironstone in North Lincolnshire:—

ANALYSES OF IRONSTONE AS RECEIVED. NORTH LINCOLNSHIRE.

—	1. Frodingham Iron and Steel.	2. Frodingham Ironstone Mines.	3. Redbourn Hill.	4. Frodingham Ironstone Mines.	5. Trent.	6. Frodingham Ironstone Mines.	7. Frodingham Ironstone Mines.	8. Frodingham Ironstone Mines.	9. Frodingham Iron and Steel.	10. Frodingham Ironstone Mines.	11.* Frodingham Ironstone Mines.
Fe	18·20	19·00	21·87	23·00	23·20	24·28	26·40	26·40	27·10	28·40	28·50
Mn	1·34	1·40	0·53	0·97	1·16	0·42	1·04	0·90	0·44	0·89	0·97
SiO_2	3·90	6·00	6·70	7·98	5·60	8·10	8·50	7·40	17·94	7·10	6·40
Al_2O_3	3·67	2·40	6·40	4·79	2·10	5·98	—	—	3·38	—	—†
CaO	26·28	25·10	22·70	16·87	20·70	14·70	14·80	17·10	7·48	14·20	14·60
MgO	1·22	1·10	—	1·43	1·20	—	—	—	1·67	—	—
S	0·10	0·06	0·06	0·39	0·12	0·06	0·24	0·32	0·05	0·42	0·26
P	0·29	0·35	0·28	0·33	0·35	0·28	0·41	0·39	0·29	0·38	0·44
Moisture	11·30	8·00	10·10	12·79	15·00	12·00	3·90	5·40	10·00	9·10	5·60
Oxygen	8·27	8·98	9·37	9·73	9·80	11·33	—	—	11·55	—	—
Difference	—	27·61	—	21·00	—	—	44·71	42·09	—	39·51	43·23
Loss on Ignition	25·74	—	21·47	—	20·50	21·60	—	—	14·67	—	—
Totals	100·31	100·00	99·48	99·28	99·73	98·75	100·00	100·00	99·57	100·00	100·00
Fe in sample dried at 212 deg.	20·52	20·65	24·33	26·37	27·30	27·60	27·47	27·90	30·10	31·24	30·19
Character of stone	Limey	Limey	Limey	Limey	Limey	elf-fluxing	Self-fluxing	Limey	Siliceous	Limey	Limey

Fig. 2. OUTPUT FROM THE CLEVELAND IRONSTONE MINES FOR EACH YEAR FROM 1860 TO 1917.



THE RAASAY IRONSTONE.

A bed of calcareous oolitic ironstone occurs near the base of the Upper Lias in the south of the Isle of Raasay.* Its strike is in general north-east and south-west, with a dip of 14 deg. to 15 deg. to the north-west.

The formation is cut here and there by north-east and south-west dislocations, causing step-faulting. These faults naturally interfere to some extent with mining operations; but where their throw has been previously determined by boring, the difficulties caused thereby can be overcome in the lay-out of the mine.

Microscopic examination of the unoxidised ore shows that the iron is practically confined to the round oolitic grains, where it occurs largely as a green silicate of iron; while the matrix between the grains consists of carbonate of lime. In the oxidised stone, which occurs where the deposit is covered by less than 12 ft. of overburden, the iron is in the form of hydrated oxide and a portion of the lime matrix has been removed by leaching. On this account this stone is higher in iron and more siliceous than the unoxidised ore. A secondary enrichment of the iron is a concomitant of the oxidation process.

The thickness of the iron ore bed varies from 5 ft. to 10 ft., averaging about 8 ft. Since a layer of about 1 ft. thickness has to be left on the roof, to prevent the overlying shale from breaking away, the working thickness of the ironstone averages 7 ft. The foot-wall is shale.

In the major portion of the proved ore field the ore body is overlaid by a considerable thickness of rock necessitating mining. Only over a small area, where there is a slight burden of peat and gravel, is open-cast working possible.

Operations are at present confined to one working, access being obtained by an adit, driven in 1,056 ft. from the surface in a north-easterly direction, and rising 1 in 100. The mine is worked to the rise, the distance from the first workings to the outcrop being 1,000 ft. to 1,200 ft.

The system of working is by "bord and pillar," the pillars averaging 40 ft. by 30 ft., with 55 ft. and 45 ft. centres respectively. At present two parallel main roads, 45 ft. apart, serve, the one for haulage and the other for men and ventilation. The endless ropeway is actuated by a motor to which power is electrically transmitted at 2,200 volts from a central station situated near the calcining kilns.

At the surface the ore is transported from the mines to the calcining kilns near the pier, a distance of 1¾ miles, by endless rope haulage, the motive power being electrically transmitted. Before passing into the calciners it is sized by breaking and screening. From a hopper at the base of the calciners, the ore is conveyed on a Robin's rubber belt to the loading shoot. The capacity of this belt is 500 tons per hour.

The pier can accommodate 5,000-ton boats, there being 22 ft. depth of water at low tide. At present 1,000-ton boats are being used, and these can be loaded in 2 hours.

The ore body has been proved to maintain its value for a distance of 2 miles along the outcrop; farther north it deteriorates in value and gradually thins out. Beyond the limits of the ground proved by boring, there is no evidence either as to iron-content or as to the thickness of the bed. There can be little doubt that it extends farther in the direction of the dip than has been actually proved.

The unoxidised ore from the mine averages about 23 per cent. of iron, with lime about 22 per cent., sulphur about 0·6 per cent. and phosphorus 0·9 per cent.

It will be seen that Raasay stone is relatively low in iron and rather high in sulphur. As a rule the stone is used in the calcined condition. The high percentage of lime makes it suitable for mixing with the siliceous clay bands of the Scotch coalfield and with tap cinder.

No. of Analysis.	Name or Situation of Quarries.	Owners.	Source of Information.
1	Scunthorpe	Frodingham Iron and Steel Company	Frodingham Iron and Steel Company.
2	Frodingham Ironstone Mines	Lord St. Oswald	North-Eastern Steel Company.
3	Redbourn Hill	Redbourn Hill Iron and Steel Company	Park Gate Iron and Steel Company.
4	Frodingham Ironstone Mines	Lord St. Oswald	Appleby Iron Company.
5	Scunthorpe	Trent Iron Company, Limited	Trent Iron Company, Limited.
6	Frodingham Ironstone Mines	Lord St. Oswald	Park Gate Iron and Steel Company.
7	" "	" "	North Lincolnshire Iron Company.
8	" "	" "	" "
9	Scunthorpe	Frodingham Iron and Steel Company	Frodingham Iron and Steel Company.
10	Frodingham Ironstone Mines	Lord St. Oswald	North Lincolnshire Iron Company.
11	" "	" "	" "

LARGE GERMAN WAR PROFITS.—The Upper Silesian Railway Requirements Company, which is also interested in mining deals, furnishes a striking example of the huge profits earned during the war by certain branches of the German industry. The following table will bear out this assertion:—

Year.	Gross Profits.	Writings-off.	Net Profits.	Dividend.
	Marks.	Marks.	Marks.	Per cent.
1913	6,800,000	3,600,000	2,600,000	4
1914	5,800,000	3,600,000	1,700,000	2
1915	12,800,000	6,000,000	6,300,000	10
1916	20,100,000	9,400,000	10,200,000	15
1917	33,700,000	15,100,000	18,100,000	20

The war profit tax has been deducted prior to the fixing of the gross profits, and this tax represents a very substantial sum, which is not specified for 1917, but which for 1915 and 1916 was provided for by a reserve of 7,600,000 marks. During 1917 more than 15,000,000 marks were expended upon extensions. For reconstruction purposes after the war, a sum of 4,500,000 marks has been set apart from last year's profits as a first instalment. The report says that the company is fully employed for months to come, but the cost of production continues to increase, whilst the prices, fixed some time ago, remain unaltered.

* The position of the Frodingham ironstone in the geological sequence (zone of Ammonites semi-costatus) was first determined by E. Cross (*Quarterly Journal of the Geological Society*, 1875, vol. xxxi, pages 115 to 130). The Pecten bed, the lowest of the Middle Lias ironstones, lies about 90 ft. above the Frodingham ironstone. It is a thin bed of ferruginous limestone, and is not worked for ironstone anywhere in the district. The Marlstone also occurs, but this is not worked in N. Lincolnshire. In S. Lincolnshire, however, it is quarried for iron at Caythorpe, near Grantham. For further details on the geology, see "The Geology of N. Lincolnshire," by W. A. E. Usher, Memoir of the Geological Survey, 1890.

† J. J. H. Teall, "The Lias Memoir." Geological Survey, page 302.

* For geological details, see "Note on the Upper Lias of the Western Islands in Reference to the Iron Ore Deposit therein," by Wallace Thornycroft, Transactions of the Edinburgh Geological Society, 1913, vol. x, page 196. And the forthcoming Memoir of the Geological Survey of Scotland.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c. of the Communicators are given in italics.

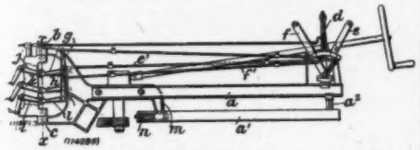
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

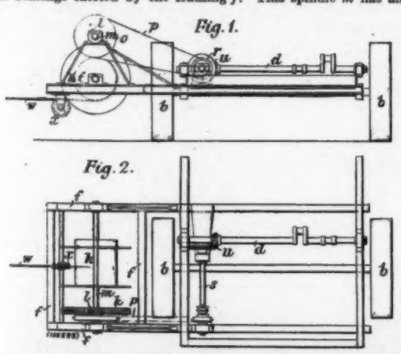
AGRICULTURAL APPLIANCES.

114,280. D. McN. Wallace, Dennistoun, Glasgow. Agricultural Tractors. (1 *Fig.*) November 7, 1917.—This invention relates to motor tractors of the two-wheel type having a rearwardly extending beam capable of a pivotal movement. *a* is the motor tractor beam which is pivoted at *b*, *c*, to the tractor framework. *d* is the control lever for the hand brake, *e* the control lever for the clutch, and *f* the control lever for the change-speed gear of the motor. The brake-control rod *d*1, the clutch-control rod *e*1, and the change-gear control rod *f*1 are, respectively, connected with vertically-moving bell cranks *g*, *h*, *i*, fulcrummed to the fork of the beam. The bell cranks, in their turn, are each connected by a universal joint to the motor controls *j*, *k*, *l*, for the brake, the clutch and the change-gear respectively. The



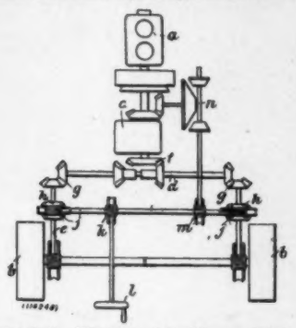
controls *j*, *k*, *l*, are vertically movable bell-crank levers which are connected to and operate the actual control rods. The universal joints are in a vertical plane and are always at the pivotal axis of the beam. No matter how the beam is turned from side to side, when steering the tractor, the universal joints always remain in the line of the pivotal axis indicated by dotted lines *x*. For the purpose of readily attaching agricultural implements the main beam *a* is made of channel section and adjustably secured to it is the auxiliary beam *a*1, this beam having, at the one end, a clamp *a*2, capable of sliding longitudinally along the main beam and at the other end it is connected to the bracket *m* and is capable of longitudinal adjustment by the screw *n*. (*Accepted April* 4, 1918.)

114,235. T. Orbell, Clare. Agricultural Tractors. (2 *Figs.*) May 7, 1917.—The invention relates to agricultural tractors. According to the invention, a winding attachment, which can be detachably affixed to the chassis of the tractor, comprises a frame *f* having rotatably mounted within it a winding drum *h*. In practice the drum *h* is arranged with its axis parallel to the longitudinal axis of the tractor and centrally with respect to the axis of the travelling wheels *b* of the latter. The spindle of the winding drum *h* has keyed upon it a spur wheel *k* which gears with a pinion *l* carried by a spindle *m*, which is mounted in bearings carried by the framing *f*. This spindle *m* has also



keyed upon it a sprocket wheel *o*, which is driven through the medium of a chain *p* by a sprocket wheel *r*, which is loosely mounted upon a spindle *s* carried in bearings beneath the tractor chassis. The spindle *s* is driven from the crankshaft *d* through the medium of bevel gear *u*, and has slidably mounted upon it a clutch part which can be brought into and out of engagement with clutch teeth on the sprocket wheel *r* so as to engage or disengage the sprocket wheel from the driving mechanism. *w* is a winding rope which passes around the drum *h*, *x* being a guide pulley which is slidably mounted on the frame *f*. (*Accepted April* 4, 1917.)

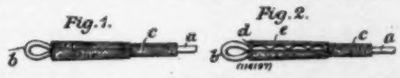
114,248. E. Williams, Edgbaston, Birmingham, and J. Newall, Ongar. Agricultural Tractors. (1 *Fig.*) June 30, 1917.—This invention provides improved mechanism whereby the effects on the direction or steering due to variations in the condition of the ground can be conveniently counteracted by the driver. From an internal-combustion engine *a*, motion is taken to each of a pair of driving wheels *b* through reduction gear *c*, a cross-shaft *d* and parallel shafts *e*. On the cross shaft reversing may be provided at *f* as shown. The shafts are connected by bevel wheels *g*. Each shaft *e* is in two parts connected by differential gear *h* in which the planet pinion carrier is preferably in the form of a worm wheel. The two differential gears are connected by a cross-shaft *i* carrying a pair of worms *j* respectively gearing with the planet pinion carriers. The worm gears are of opposite hand so that rotation of the cross-shaft produces opposite rotations of the said carriers. In one arrangement, the cross-shaft is rotatable through reduction gear *k*, by a hand wheel *l* under the control of the driver. Or, alternatively the cross-shaft is driven through worm gear *m* in either direction by friction gear *n* receiving its motion from the engine under the control of the driver. When the resistance of the ground on the driving wheels is uniform, the vehicle moves in a straight line. To change the course, the cross-shaft *i* is rotated, thus setting up a change in the relative speed of rotation of the driving wheels. The variation of the course depends upon the direction of rotation



of the cross-shaft. When an obstruction or other condition, such as a soft place in the ground, is encountered by one of the driving wheels tending to deviate, the vehicle the speed of that wheel is increased and of the other decreased by the operation of the cross-shaft to maintain the original course. (*Accepted April* 4, 1918.)

ELECTRICAL APPARATUS.

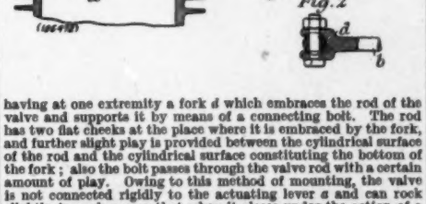
114,197. J. H. Ward and M. H. Goldstone, Salford. Electrical Cables. (3 *Figs.*) March 22, 1917.—The improvements relate in particular to cables or conductors used with telephones and electrical heating appliances. According to the improvements, the braiding, after being applied as usual to each conductor (or tag) end is continued back upon itself for a distance, say, rather greater than the length of the tag end, thereby providing a neat edge next the exposed part of the conductor, and the raw end of the braiding terminating at that part of the



tag end furthest from the exposed end of the conductor, where it may be covered by the usual outer covering of the cable or conductor. The end of each conductor *a* is formed with a loop *b* by doubling said conductor back on itself and binding the extreme end to the main strand. The braiding *c* is doubled back on itself at *d*, and an additional layer of braiding *e* applied above the layer *c*. The layer *e* is carried as far back as desired to produce a neat termination and sufficient to prevent said braiding becoming unravelled and exposing the connection joint. (*Accepted April* 4, 1918.)

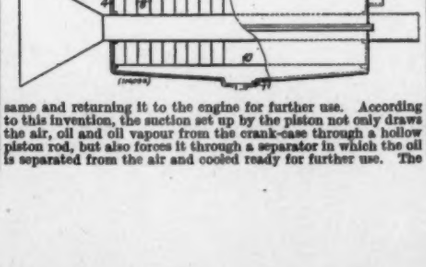
GAS ENGINES, PRODUCERS, HOLDERS, &c.

106,472. Societe des Moteurs Gnome et Rhone, Paris, France. Internal-Combustion Engines. (3 *Figs.*) April 3, 1916.—This invention relates to valve-actuating mechanism for internal-combustion engines. The invention consists in an operating mechanism for valves of internal-combustion engines in which the usual guiding means is dispensed with, the valve which is of the ordinary mushroom type being directly hung by its stem on the actuating lever by means of a connection having a certain amount of play, so as to give the valve a certain amount of freedom, especially in a flat-wise direction along its seat. The valve *a* is mounted directly on the actuating lever *b* and



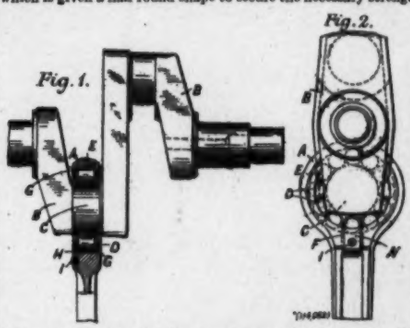
having at one extremity a fork *d* which embraces the rod of the valve and supports it by means of a connecting bolt. The rod has two flat cheeks at the place where it is embraced by the fork, and further slight play is provided between the cylindrical surface of the rod and the cylindrical surface constituting the bottom of the fork; also the bolt passes through the valve rod with a certain amount of play. Owing to this method of mounting, the valve is not connected rigidly to the actuating lever *a* and can rock slightly in such a way that when it closes under the action of a spring *n* it can close perfectly on its seat. (*Accepted April* 4, 1918.)

114,092. S. S. Guy, Finchfield, Wolverhampton. Internal-Combustion Engines. (1 *Fig.*) July 25, 1917.—This invention has reference to internal-combustion engines of the tandem and double-acting type, and consists in the provision of improved means for separating the oil from the air, cooling the



same and returning it to the engine for further use. According to this invention, the suction set up by the piston not only draws the air, oil and oil vapour from the crank-case through a hollow piston rod, but also forces it through a separator in which the oil is separated from the air and cooled ready for further use. The cylinders 2, remote from the crank-case, each communicate by means of a non-return valve 3 with a chamber 4, and the pistons of the said cylinders into which the hollow piston rods 5 project are each similarly provided with an oppositely acting non-return valve 6, the arrangement being such that during the instroke of each piston a charge of oil and air is induced from the crank chamber through the hollow piston rod and past the non-return valve 6 on the piston 7 into the outer end of the cylinder aforesaid. On the outward stroke of the piston this charge of air, oil and oil vapour is forced past the non-return valve 3 into the chamber 4 where it is made to pass through a series of gauze screens 8 which effectually condense the oil vapour and separate the oil from the air, the latter passing out through a vent 9 into the atmosphere, whilst the oil passes through a strainer 10 into a sump 11, whence it can be drawn off for further use. (*Accepted March* 27, 1918.)

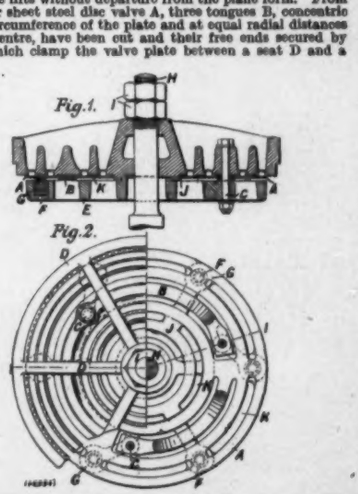
114,052. W. Douglas, Kingswood, Bristol. Connecting Rods and Cranks. (2 *Figs.*) April 10, 1917.—This invention relates to a two-throw crank in which the cranks are 180 deg. apart. According to this invention, the connecting rod big-end has an internal annular recess to form a roller outer race and a slot is made through one of the roller-containing flanges formed on each side of the recess. A is the big-end of a connecting rod which is given a half round shape to secure the necessary strength



without interfering with its passage over the crank-web. The outer crank-webs B are at a suitable angle to the shaft to facilitate the passage of the big-end over them. That end of the crank web B which adjoins its crank-pin C is slightly under the periphery of the said crank-pin; and the rollers D can be inserted into the annular recess E in the big-end, through the slot F in one of the flanges G formed on each side of the recess. The slot is closed by a dove-tailed slip of metal H which is held in position by a grub screw I. (*Accepted March* 27, 1918.)

HYDRAULIC MACHINERY.

114,094. Galloways, Limited, Manchester. Valve. (2 *Figs.*) September 14, 1917.—The invention relates to an automatic valve of the type in which the valve is formed of a plane circular sheet of elastic material fixed to the valve seat by elastic concentric connecting strips which may be tongues or flaps cut from the valve plate. According to the invention, the tongues are secured to the seating or guard at points between the centre and the outer periphery of the valve, whereby the whole surface of the valve lifts without departure from the plane form. From the circular sheet steel disc valve A, three tongues B, concentric with the circumference of the plate and at equal radial distances from the centre, have been cut and their free ends secured by bolts C, which clamp the valve plate between a seat D and a

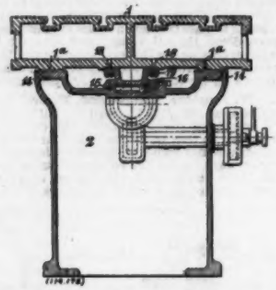


guard E. The valve A is pressed against the seat D partly by light springs F, of which six are provided in the construction shown, and partly by the elasticity of the tongues B. The springs F are fitted in recesses G provided in the guard E, which is accurately centred by an annular projection fitting in a corresponding recess in the seating D. The bolt H and nuts I serve to connect the valve seating D with an adjacent valve seating, one seating usually belonging to a suction valve and the other to a delivery valve; the bolts with suitable shoulders thereon securing both seatings in the air-box, cylinder cover or other position. The central portion J of the valve plate is removed and concentric circular slots K are provided in the plate (*Accepted March* 27, 1918.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

114,178. G. Richards, Westminster. Metal-Planing Machines. (5 *Figs.*) March 16, 1917.—This invention relates to metal-planing machines and consists in certain improvements in the method of forming, supporting and guiding the reciprocating table whereon the work is fixed, in the method of attaching the rack whereby the table is operated, and in the means whereby the rack and guide surfaces are lubricated. The rack 7 is utilised to guide the table upon its bed; the said rack bearing on one side against a projection 15 formed on the bed 2, and on the other side against an adjustable strip 16 with which the bed is fitted. The rack 7 is fixed on the table in such a manner as to

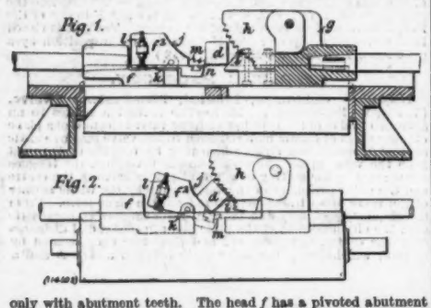
facilitate the use of the former as a gauge in manufacturing the bed. For this purpose, the rack 7 is made with two projections or lips 18, 18, to enable strips 19, 19, to clamp the rack to the underside of the table. The rack 7 can be put in place or removed by loosening the screws in the strips 19, 19. The surfaces 14, 14, of the bed 2 can be planed and scraped to a flat surface plate and completed in advance of the table 1. The table can have its surfaces 1*a*, 1*a*, accurately scraped to a flat surface plate, in-



dependently of the bed, and either before or after the bed is completed. The rack can be prepared parallel, to gauges, and then used as a testing-piece to adjust the surfaces on the bed, and also for setting the strip 16 to afford the rack the necessary working freedom. From the foregoing, it will be realised that the operations incidental to the preparation of the beds, tables and racks, are to a great extent independent one of another; the manufacture of such machines being thereby greatly facilitated. (*Accepted April* 4, 1918.)

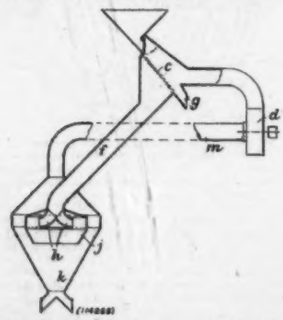
MINING, METALLURGY AND METAL WORKING.

114,103. W. Williams, Gilwern, Breconshire. Manipulating Ingots. (2 *Figs.*) August 8, 1917.—This invention relates to apparatus for manipulating ingots, blooms, billets, bars and the like in rolling mills, and is an improvement in or modification of the invention described in Specification No. 108,050. According to the present invention, the abutment head comprises an abutment portion or jaw which is mounted to tilt or rock on a pivot while its operative surface is made slightly concave and formed or provided preferably on a portion



only with abutment teeth. The head *f* has a pivoted abutment portion or jaw f^2 with which the head *g* with the movable and fixed jaws *h*, *i*, co-operates to turn the work *d*, the operative part *j* of the jaw f^2 being curved and provided with abutment teeth *m* formed on a detachable piece *n* with a dovetail fixing. The jaw f^2 is pivoted between upstanding lugs or cheeks on the head *f* on a pin *k*, about which it can tilt to a limited extent, and is adjusted by screw stops *l* fixed in lugs on each side of the head. (*Accepted March* 27, 1918.)

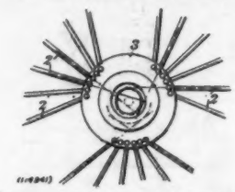
114,288. G. W. S. Simpson, London. Pneumatic Separators. (2 *Figs.*) December 17, 1917.—This invention relates to a pneumatic separator of the kind in which the material descending a screening surface consisting of louvres arranged to form an inclined plane, meets a transverse current of air which moves in a closed circuit. By this invention the separator comprises a screening surface *c* consisting of a number of louvres arranged to form an inclined plane and preferably adjustable to vary the openings between them. The material to be separated is caused to descend this inclined plane against which is blown a current of air; this current carries the smaller and lighter



particles between the louvres, while the larger and heavier particles fall into a shoot *g* and are discharged from the apparatus. The current of air blown between the louvres and laden with particles is conveyed by a pipe *f* into a separator of the cyclone type; here the pipe terminates in a number of curved outlets *h* adapted to impart to the air current a spiral or cyclone motion within a hood *j*, into which the said outlets discharge. This hood *j* is contained in a closed hopper *k* from which the collected dust is discharged while the air returns from the hopper through a pipe *m* connected with the intake of the blower *d* creating the air current. (*Accepted April* 4, 1918.)

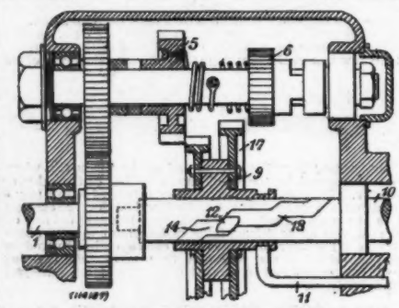
MOTOR ROAD VEHICLES.

114,241. W. A. Starley, Earlsdon, Coventry. Wire-Spoked Wheels. (2 *Figs.*) June 11, 1917.—This invention has reference to wire-spoked wheels. According to this invention, the outer ends of the spokes 2 are as usual equi-distantly spaced around the rim or felloe, but at the hub their inner ends are arranged in equi-distant groups around the hub flanges 3. The said groups at one end of the hub may be either arranged opposite those at the other end of the hub or alternate therewith. In



either case the arrangement is preferably such that none of the spokes are radial, *i.e.*, assuming there are three groups of six spokes in each group the two middle spokes of each group are tangential to the opposite sides, of a comparatively small imaginary circle concentric with the axis of the hub, whilst the other spokes on each side are tangential to similar circles of greater diameter than the first imaginary circle, but not exceeding that of the hub flanges. (*Accepted April* 4, 1918.)

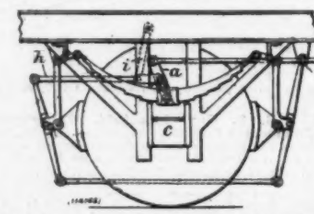
114,187. E. Fairweather, London. Variable-Gear Transmission Gear. (3 *Figs.*) March 20, 1917.—The present invention relates to variable-ratio transmission gearing of the type in which one or more of the gear wheels transmitting the drive are slidable axially into or out of driving connection with other pinions. The member 9 displaceable for the purpose of altering the ratio of transmission of drive from the driving shaft 1 to the driven shaft 10, is displaceable along said shaft by the usual gear-striking lever 11, and carries a pin 12 engaging with a helical groove 13 cut in the shaft 10, which has parts 14 upon



it which are truly axial to the shaft 10, these parts being connected by the helical parts 13. The effect of this is that when the gear wheel 16 is in engagement with the gear wheel 5, the pin 12 is lying in the space 14, and consequently there is no tendency for the gearing to come out of engagement. As the member 9, however, is displaced by means of a lever 11, to bring the gear wheel 16 out of engagement with the gear wheel 5, it is given a negative movement of precession to reduce its peripheral velocity so that the peripheral velocity of the wheel 17 is also reduced to approximate better the peripheral velocity of the pinion 6 with which it is about to engage a further movement of the striking lever 11. (*Accepted April* 4, 1918.)

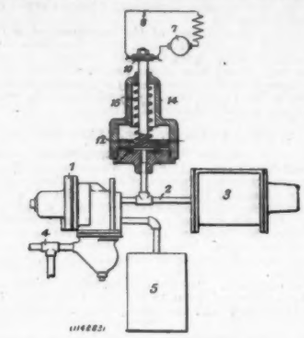
RAILWAYS AND TRAMWAYS.

114,168. G. B. Bowles, Forest Gate. Brake Apparatus. (2 *Figs.*) February 16, 1917.—This invention relates to hand power-operated brake apparatus for railway wagons of the type wherein the power by which the brake is operated is applied directly to the brake mechanism through a rigid connection, and wherein the leverage of the brake mechanism is altered automatically to suit the load, being increased when the load increases and reduced when the load is reduced, so that with the same power exerted to apply the brakes, the pressure of the blocks against the wheels shall be respectively increased and reduced. According to the present invention, the movements of the body of the vehicle are caused automatically to vary the effective point of connection between a lever *a* and link *i* used for directly transmitting the power applied through a draw rod or equivalent rigid connection to the brake block or blocks of the vehicle. In an arrangement of this kind, the lever *a* may be



mounted to turn in a vertical plane about a fulcrum carried by a part of the vehicle that does not rise and fall with the body thereof, as for instance by one of the axle boxes C of the vehicle, and be formed with a longitudinal slot into which extends a pin carried by one end of a draw or push rod or link *h* which is connected by a suspension link *i* to the vehicle body, the arrangement being such that the rod or link *h* will fall and rise with the vehicle body, under the action of increased or reduced load, and vary the position of the pin in the slot in the lever *a*. In this way the effective value of this lever will be varied to vary the pressure with which the block or blocks can be applied to the wheels of the vehicle, to suit the load, without varying the initial power used to apply the brake and, at the same time, vary the normal distance of the brake blocks from the wheel or wheels and avoid any necessity for varying the travel of the hand or power-actuated means used to apply the brake. (*Accepted April* 4, 1918.)

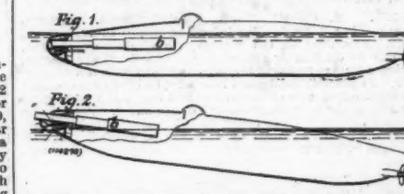
114,283. W. V Turner, Wilkinsburg, U.S.A. Fluid Pressure Brakes. (1 *Fig.*) June 30, 1917.—This invention relates to a brake equipment in which a fluid pressure brake and a regenerative brake is employed. The fluid pressure brake equipment comprises a triple valve device 1 for supplying and releasing fluid under pressure through pipe 2 to and from the brake cylinder 3, a brake pipe 4 connected to the triple valve device 1 and the usual auxiliary reservoir 5. The regenerative brake is represented diagrammatically by a motor generator 7 connected in a regenerative circuit 8. A switch controls the regenerative circuit 8 and comprises fixed contacts connected in said circuit, and a movable contact 10 adapted to open and close the regenerative circuit through the fixed contacts. The movable contact 10 is connected to a piston 12 contained in a



switch casing 14. A spring 15 tends to hold the switch closed and the casing 14 is connected to the pipe 2. In operation, when the fluid pressure brakes are applied, fluid under pressure is supplied by the triple valve device 1, through pipe 2, to the brake cylinder 3 in the usual manner, fluid also flowing to the seated area of piston 12, thereby causing the piston to lift from its seat. The full area of the piston 12 is then exposed to brake cylinder pressure and the prompt and sudden movement of the piston to open the switch is effected. It will now be evident that when the fluid pressure brakes are applied, the regenerative braking circuit 8 is opened, so that the regenerative brake cannot be brought into action, but so long as the fluid pressure brakes remain released, the regenerative brake circuit is held closed, permitting the regenerative brake to act in the usual manner. (*Accepted April* 4, 1918.)

SHIPS AND NAUTICAL APPLIANCES.

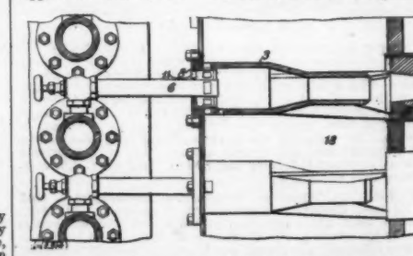
114,270. J. Fielding, Gloucester. Submersible Gun-boat. (2 *Figs.*) September 26, 1917.—The invention relates to submersible boats, and it consists in improvements, the characteristic features of which are that the boat is equipped with a single large gun *b* which is so mounted that normally, while



the boat is being navigated, it remains submerged, but whose muzzle can be alternatively brought above the surface of the water by trimming the boat to such an angle as will give the necessary elevation of the gun, not merely for the muzzle to clear the water, but also for the desired range of fire to be attained. (*Accepted April* 4, 1918.)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

113,314. P. St. G. Kirke, Westminster. Furnaces. (8 *Figs.*) February 15, 1917.—Gaseous fuel and air for heating steam generators, feed-water heaters, and liquids generally are mixed first in a primary mixing chamber 3, and afterwards in passing through a secondary mixing chamber such as the central aperture in a plug B at the entrance to the boiler tube. The apparatus is described in connection with a multi-tubular boiler, each tube of which is fired by a separate burner. The gas is supplied at the front of the boiler by pipes or nozzles 6 attached to horizontal branches on a vertical extension of the gas main. Air enters through regulators 8 in quantities insufficient to support combustion, and the mixture made in the primary



mixing chamber 3 passes through the secondary mixing chamber in the plug B, entraining from the hot-air space 18 sufficient air to complete the combustion of the gas. The mixture passes through the plug at a velocity greater than that of the mixtures in the chambers 3 or in the tubes, the near ends of which may be lined with refractory material. Combustion may be completed on refractory material in the tubes, preferably arranged as described in Specification 17842/15. A sight hole 11 is provided. A third mixing chamber may be arranged between the secondary mixing chamber and the combustion chamber. The air may be heated by the waste heat of combustion, and the apparatus is preferably worked under exhaust draught produced by a fan. (*Sealed.*)